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NOTES ON THE EFFECTS OF PHYSICAL FACTORS ON THE SPRUCE BUDWORM, *CHORISTONEURA FUMIFERANA* (CLEM.)

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(Continued from P. 170, Nos. 9, 10)

Concerning the light reactions of the adults, it may be noted that males are photopositive when in a dark-adapted state, but they rapidly become adapted to any light intensity and become extremely sluggish. Females in the dark-adapted state exhibit either photonegative behaviour or compassing behaviour, with no evidence that there is any orderly transition from one type of behaviour to the other. Light-compass orientation of flying females makes it possible to collect some at light traps, despite their normally negative response.

When light-adapted, females also become sluggish. The effect of this light-induced "sleep" of both sexes is reflected in the field by the fact, that during daylight hours, moths are normally inactive. If they are disturbed, they move only a short distance before settling again. When the light intensity decreases rapidly during the crepuscular period, flight activity of the adults increases.

The foregoing notes have covered some of the points of immediate interest which have been brought out by studies of the effects of weather factors on the activity and behaviour of the spruce budworm. Actually, such studies may be considered to be in the nature of preliminary tests applied to determine the advisability of more varied meteorological studies of this insect. The program has proved sufficiently productive to warrant the future addition of long-term studies, by laboratory, phenological and climatological methods, of the effects of weather and climate on the survival and consequent distribution of the species.

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THE INFLUENCE OF SPRAY PROGRAMS ON THE FAUNA OF APPLE ORCHARDS IN NOVA SCOTIA: II. OYSTERSHELL SCALE *Lepidosaphes ulmi* (L.) *

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(I) INTRODUCTION

In the first paper of this series (5) the ecological approach to apple orchard insect problems was discussed and it was pointed out that the spray program must be considered as an ecological factor. It is obvious that because of the complex relationships of the plant and animal species in an orchard it is impossible to change the relationships of any single species without, in greater or lesser degree, altering the whole community. In some cases the disturbed relationship may show immediately in the repression of one pest and the rise of another, while in other cases the changes are much more obscure and the economic effects may not appear for a long time. The cause of these changes is that a spray aimed at some particular species also, directly or indirectly, affects many other species in the orchard environment, and thus may be expected to alter the numerical relationship of many predacious and parasitic forms to certain pests or potential pests which are their prey. The oystershell scale, *Lepidosaphes ulmi* (L.), and the European red mite, *Metatetranychus ulmi* (Koch) = (*Paratetranychus pilosus* (C & F)) are examples of species which react quickly to changes in spray treatments owing to the large populations they may build up in a short time and to the rapid increase of their predators and parasites when not hindered by the spray treatments.

In Nova Scotia, in commercial orcharding, it is always necessary to use a series of fungicidal sprays for the control of apple scab, *Venturia inequalis* Wint. Each of the fungicides in general use, and so far studied, directly affects a portion of the orchard fauna but each differs in the species affected, in the degree to which the latter are numerically influenced, and thus in the degree of change in the ecological relationships of the species. When the species directly suppressed by the spray are parasites or predators there will be an increase in the host species unless the latter are themselves destroyed by sprays.

This paper is mainly confined to studies on the influence of the fungicides on the oystershell scale and its principal natural enemies, the chalcid *Aphelinus mytilaspidis* LeB. and the predacious mite *Hemisarcoptes malus* (Shimer). Coincident with these studies has been an attempt to record as many as possible of the changes in the arthropod populations following each spray treatment. The influence of sprays on the natural control of the oystershell scale cannot, in practice, be considered without reference to the over-all effect on other species but for convenience in discussion it will be necessary to refer only briefly to the more pertinent results and leave the details for later papers from this laboratory.

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(2) HISTORY OF SPRAY PRACTICES IN NOVA SCOTIA WITH SPECIAL REFERENCE TO THE OYSTERSHELL SCALE

It is difficult to obtain a clear picture of the magnitude of the oystershell scale problem in Nova Scotia during the earlier years to which references can be found. It was, however, of sufficient importance for many years to merit attempts to obtain control although it is doubtful if some of the materials rather naively recommended were really effective in bringing about the degree of control that apparently followed their use. In the light of present knowledge it would seem that many of the materials must have been successful owing to their ineffectiveness against the natural control agents rather than through any direct effect on the scales. It is quite true that individual trees, or groups of trees, can be found heavily coated with scales even though they have never received a spray treatment of any kind. Almost invariably most of the scales in such cases are found to be old ones still clinging to the bark while a high percentage of the living ones are being attacked by natural enemies. It is impossible to state why these sporadic outbreaks occur on neglected trees but they may be due simply to temporary fluctuations of its natural control agents which occasionally allow it to increase.

Since about 1930, the oystershell scale, instead of attacking isolated trees or parts of orchards, has become a major pest throughout many orchards, most of the worst infestations being in those which have been well sprayed. In these cases it has become necessary to apply a dormant oil spray every three or four years to reduce the scale population. A very brief review of the history of spray practices in the Annapolis Valley, given below and based largely on a paper by Kelsall (4) covering the period up to 1937, has been used as the basis for interpreting the present oystershell scale situation. Some additional data have been taken from official spray calendars.

Spraying of apple orchards had become fairly general by 1908 and a number of growers had changed from the use of bordeaux mixture to lime-sulphur as a fungicide by 1910. Brittain (1) in 1915 stated that the most satisfactory treatment for scale was a dormant lime-sulphur application, but if the regular post-blossom fungicide spray of lime-sulphur was delayed a few days, it effected control of the insect by destroying the newly hatched 'crawlers' emerging from under the old scales. Brittain also referred to miscible oils as then being on the market but did not advise their use. Sanders and Brittain (6) in 1918 pointed out that the increased use of high power sprayers and greater capacity nozzles was causing considerable damage to the foliage and they began work on excess lime bordeaux mixtures. During the 1920's there was very little mention of the oystershell scale as a pest but from 1926 to 1936 nicotine sulphate was recommended in the Nova Scotia spray calendar for its control. This was applied at the rate of one pint to 100 gallons of spray when the scales were crawling in June. After 1928 dormant 3 per cent mineral oil sprays were recommended for outbreaks of the European red mite which had become a problem about this time. It was not until 1935 that a dormant 5 per cent mineral oil was officially recommended for the control of oystershell scales. In 1941 an alternative to the dormant 5 per cent mineral oil was a proprietary dormant 2 per cent oil containing dinitro-ortho-cyclohexylphenol. This was changed in 1943 to a dormant 5 per cent mineral oil and, as an alternative, dormant 4 per cent mineral oil to which was added 1¼ pounds of 40 per cent dinitro-ortho-cresol. This latter recommendation continues in use at the present time.

It is now known that the fungicides applied in an orchard may greatly affect the natural control of oystershell scales. During the years in which lime-sulphur was the standard fungicide (about 1910 to 1918) the oystershell scale was not a major problem in the Annapolis Valley. From 1918 to 1924 copper-lime and sulphur fungicide dusts were very widely used in the Annapolis Valley but after that period the growers returned to liquid sprays, particularly lime-sulphur or lime-sulphur precipitated with aluminium sulphate or iron sulphate. During the period immediately following the use of dusts the oystershell scale which had become somewhat of a problem again, began to decline owing to the return to lime-sulphur. From then until 1932 the scale received little mention as a pest but from about 1932 on it demanded increasing attention. Flotation sulphur and wettable sulphurs commonly began to be used in the blossom period sprays after 1932 and up until the present have been very widely employed. The widespread outbreaks of oystershell scale in well sprayed orchards and the need for special control measures have coincided with the period during which these mild sulphur sprays have been in use. It has already been pointed out that since 1935 special scale control recommendations based on oil have been made in the spray calendar.

The present spray program in most of the commercial orchards in the Annapolis Valley consists of six fungicide applications including an arsenical insecticide. This consists of two bordeaux applications followed by three sprays of one of the mild sulphurs and ending with another bordeaux treatment. A comprehensive survey, by the staff of the Annapolis Royal Entomological Laboratory, of scale-infested orchards in which this program was followed showed that, in general, the chalcid parasite *Aphelinus mytilaspidis* LeB. and the predacious mite *Hemisarcoptes malus* (Shimer) were not present in sufficient numbers to keep the scale under control. This observation led to the first experiment, started in the Palmer orchard in 1943, on the effect of the sprays on the natural control of oystershell scale. This was later expanded in larger blocks of orchard from 1945 to the present. A description of the experimental orchards has already been given by Pickett et al. (5).

(3) METHODS OF STUDY

A survey of oystershell scale in commercial orchards has been made each winter, from 1942 until the present, since it is possible at that time to determine the percentage of the scales that has survived and also to appraise the causes of destruction of the scales. In 1944 and 1945 extensive examinations of scales were made in the experimental orchards during the summer months by dissection under a binocular microscope. As it was important to have a detailed knowledge of the three species involved, a brief study was made during 1944 of the bionomics of the oystershell scale of *Aphelinus* and of *Hemisarcoptes*, chiefly in the Palmer orchard where all three species were abundant in the plot sprayed with Fermate. This was done by examining samples of scales every few days and recording the numbers and the stage of the scale and its two natural control agents.

During 1945 samples of scales from several trees in each plot in the Palmer orchard were examined periodically to measure the influence of the spray materials. As there are three generations of *Aphelinus* it was possible to time the date of examination so as to coincide with the periods in which the parasites of each generation were mostly in an advanced larval stage. *Hemisarcoptes* is found in all stages of development throughout the summer so the timing of the examinations was not so important.

A considerable portion of the examination was delayed until the winter months since it is possible at this time to determine to a great ex-

tent the causes of the destruction of the scales during the earlier months of the year. If large numbers of scales were killed in the first or early second instar it may be inferred that most of these were destroyed by *Hemisarcoptes*, because first instar scales are not attacked by *Aphelinus*. It is difficult to determine the cause of mortality among second instar scales since the parasite adults emerging from them do not always leave exit holes, escape often being achieved from under the edges of the scales. Emerging second generation *Aphelinus* leave exit holes in the third instar scales and the third generation larvae of this species are found overwintering under the scales. Mites attacking third instar scales may simply leave the dead insect body behind or, if they have attacked the eggs, they will either be present themselves or the scale eggs destroyed by them will have a very characteristic appearance.

The method in use at present in making an examination of scales on a twig is to carefully turn over all scales in the microscope field and then to take at random other fields until a total of twenty-five scales have been examined. Tests of this method revealed that by thus examining about twenty-five scales from each of twenty twigs, selected at random over a plot or orchard, comparable results could be obtained.

(7) NOTES ON THE BIONOMICS OF THE OYSTERSHELL SCALE AND ITS BIOLOGICAL CONTROL AGENTS

(*a*) *The Oystershell Scale*

Griswold (3) described in detail the biology of the oystershell scale and, with a few modifications, this applies to the life history of the scale in Nova Scotia. There is only one generation a year in Nova Scotia, the winter being passed in the egg stage protected by the scaly covering of the parent which dies shortly after oviposition is completed. Each female produces about thirty eggs which hatch from the first to the third week of June depending upon the season. The scales usually reach the second instar during the latter part of June and this stage may persist until the last of July. The third instar develops during August, oviposition beginning about the middle of August and continuing into September.

(*b*) *Hemisarcoptes mallus* (*Shimer*)

A discussion of the importance and history of *Hemisarcoptes* was given by Tothill (7) in 1919 and Ewing and Webster (2) in 1912 discussed the synonomy of this mite in some detail. In Nova Scotia the mites pass the winter mostly in the advanced immature stages and eggs are seldom found at this time. In the latter part of May and early in June (just before the eggs of the oystershell scale hatch) gravid female mites are found under the scales, laying eggs in great abundance. These eggs are pearly white and cylindrical in shape, more shiny than those of the oystershell scale and much smaller. They hatch about the same time as the scale eggs and many of the protonymphs attach themselves to the scale larvae before the latter begin to migrate. The mite eggs are found throughout the season but two peaks of abundance seem to occur, the first under the old scales in June and the second under third instar scales about the time the latter are ovipositing. The mites indiscriminately attack all stages of the scale including the eggs; the stage most affected varies with the time at which the mite reaches its greatest abundance. *Hemisarcoptes* is most effective when the scales are abundant so that it is very common to find a much lower percentage of scales infested when the latter have become scarce.

(*c*) *Aphelinus mytilaspidis LeB.*

Griswold (3) also gave an account of the biology and synonomy of the chalcid parasite *A.mytilaspidis*. As with *Hemisarcoptes* only sufficient details of the biology were worked out in Nova Scotia to facilitate mea-

surement of the effect of the sprays upon the parasite. Adults of the overwintering generation emerge at the time the second instar scales are forming (about the first week in July) and oviposit in them. The first generation of parasite larvae develops in this instar and adults emerge, usually under the edges of the scales, early in August. The adults of this generation oviposit in third instar scales and larval development proceeds prior to and during the early period of the scale oviposition. Adults of the second generation emerge during September and are found throughout most of the month. The larvae of the third generation overwinter under the scales.

Table 1. Seasonal Development of the Oystershell Scale and Its Natural Enemies in 1944

Date	Oystershell scale	*A. mytilaspidis*	*H. malus*	Spray application
Winter	Eggs	Larvae	Mites (no eggs).	
May 22	Eggs	Larvae	Mites & eggs.	Pink
May 27	Hatching	Larvae	Eggs hatching.	
June 2	Crawling	Larvae	Small Mites.	Calyx
June 16	2nd instar forming	Pupae	Mites	1st Cover
July 4	2nd instar	Adults	Mites & eggs.	2nd Cover
July 24	3rd instar forming	Pupae	Mites & eggs.	
Aug. 7	3rd instar	Adults	Mites & eggs.	
Aug. 23	Ovipositing	Larvae & Pupae	Mites & eggs.	
Sep. 15	Ovipositing	Adults	Mites & eggs.	
Winter	Eggs	Larvae	Mites (no eggs).	

(5) THE RELATION BETWEEN THE OYSTERSHELL SCALE AND ITS NATURAL ENEMIES IN EXPERIMENTAL ORCHARDS

(a) Results from the Palmer Orchard

The first planned experiment on the effect of fungicides on the natural enemies of oystershell scale was begun in 1943 in the Palmer orchard where a number of dormant treatments were compared with preblossom treatments of bordeaux and sulphur sprays. The later applications were made by the owner and included several flotation sulphur sprays. In addition to these experimental plots, two rows at the north end of the orchard received six applications of Fermate (ferric dimethyldithiocarbamate) which was the only material used on this plot throughout the season. Upon examination the following winter it was found that there had been an increase of *Aphelinus* and *Hemisarcoptes* on the Fermate plot but practically no natural enemies were present in the rest of the orchard. These treatments also brought about considerable differences in the scale population on the various rows. In 1944 three more adjoining rows were added to the Fermate plot and the remaining portion of the orchard was divided into single row plots (in duplicate) on which lime-sulphur, copper (C.O.C.S.* and bordeaux mixture), flotation sulphur and Fermate (one row) were used. These treatments were continued in 1945 and 1946. It was soon found that in work of this nature small plots are of limited value although some valuable information was gathered from this particular experiment. During the course of the experiment large numbers of *Aphelinus* developed on the Fermate block and some appeared on the copper plots but none on the sulphur plots in the summer. There was very little migration of adult parasites from the Fermate and copper plots to the sulphur plots during the spraying season but in September second generation *Aphelinus* adults migrated in large numbers to the sulphur plots, presumably because very little sulphur residue was left by that time on the trees. In larger plots the effect of the fall migration probably would have been minimized although in certain orchards there is some indication that such mi-

* C.O.C.S. is a proprietary preparation of Copper ozychloride sulphate.

gration does occur from other scale-infested plants in the vicinity or from adjoining blocks of orchard where conditions are favourable for parasite production. For this reason, when winter examinations of the Palmer plots were made, it was found that the parasite larvae were almost as numerous on the sulphur plots as on the Fermate plots. *Hemisarcoptes,* although apparently able to find means of transportation from one tree to another, moves about much less readily than *Aphelinus* and thus did not show any sudden increase in numbers late in the season on sulphur sprayed trees.

The two single-row plots receiving copper and the single row receiving Fermate were located between sulphur treatments so that they became contaminated by spray drift from the sulphur plots. Whereas copper or Fermate drift had no influence on the sulphur plots, sulphur spray drift had an important effect on the single-row copper and Fermate plots. For this reason a discussion of the effect of copper sprays has been left to a later section dealing with the Hiltz-South Yarmouth experiment where much larger plots were used.

The results with Fermate and sulphur sprays in this orchard were clear-cut, and in some ways the limitations of small plots served to illustrate even more clearly the effect of these sprays on the natural control agents of oystershell scale. The rapid decline in the scale population in the five-row Fermate plot was much more marked than in the single copper and the single Fermate row located between the sulphur plots (Table 2), evidently owing to the influence of sulphur spray drift on the single-row plots. From Table 3 and Fig. 1 it will be seen that there was a moderate amount of parasitism in all plots in the late fall of 1944 owing to fall migration of the second generation of *Aphelinus* adults. In the spring of 1945, however, parasitism (and predation) remained high on the Fermate plot, dropping only later in the season as the numbers of healthy scales declined. With sulphur there was an immediate drop in parasitism in the spring of 1945, rising again only with the fall migration of adult parasites after the sulphur had weathered from the trees. This was accentuated in the fall of 1945 by the lack of living scales on the Fermate plot which forced the parasites emerging from the last of the scales on that plot to search for hosts on the other plots.

The contrast between the numbers of *Hemisarcoptes* on the Fermate and sulphur plots was much more marked than was the case with *Aphelinus,* the sulphur sprays having kept the mites at a very low level throughout the year and there was not the levelling effect from migration late in the season which occurs with *Aphelinus.*

Lime-sulphur was very detrimental to the natural enemies of the scales but there was no increase in the scale population, apparently because of the direct toxicity of lime-sulphur to the scales. Flotation sulphur apparently had very little toxic action on the scales but the effect on the natural control agents was severe. It is interesting to note (Table 2) that in row 13 (flotation sulphur) which was treated with dormant oil in 1943 a heavy population of scales developed more rapidly than in row 9 which was also sprayed with flotation sulphur but which received no oil treatment.

Table 2. Fall Populations of Mature Oystershell Scale per 100 Terminals in Palmer Orchard Plots, 1943 - 1946. (Basal two inches of each terminal examined)

Row	Treatment 1944 - 1946	1943	1944	1945	1946
1 & 2	Fermate*	724	58	1	1
3 - 5	Fermate	264	562	3	6
6 - 7	Lime-sulphur	554	233	36	138
8	Bordeaux & C.O.C.S.	576	1364	41	472
9	Flotation sulphur	692	550	633	1036
10	Fermate	394	584	256	210
11	Lime-sulphur	352	166	203	127
12	Bordeaux & C.O.C.S.	90	166	37	111
13	Flotation sulphur	34	76	194	1329

* Fermate in 1943 also

Table 3. Percentage of Scales Attacked by *A. mytilaspidis* and *H. malus* in the Palmer Orchard, 1943 - 1945

Percentage of scales with Aphelinus mytilaspidis

Row	Treatment 1944 - 1946	1943 scales Mature scales	1944 scales Instar 1st.	1944 scales Instar 2nd.	1944 scales Instar 3rd.	1944 scales Mature scales	1945 scales Instar 1st.	1945 scales Instar 2nd.	1945 scales Instar 3rd.	1945 scales Mature scales
1 & 2	Fermate*	16		11	29	24		13	22	7
3 - 5	Fermate	1		2	6	33		23	20	7
6 & 7	Lime-sulphur	1		0	0	20		3	10	26
8	Bordeaux and C.O.C.S.	0		0	0	26		17	35	25
9	Flotation sulphur	1		0	0	9		1	1	22
10	Fermate	0		0	0	11		9	37	29
11	Lime-sulphur	-		-	-	15		0	3	31
12	Bordeaux and C.O.C.S.	-		-	-	31		14	23	27
13	Flotation sulphur	-		-	-	10		0	1	19

Percentage of living scales with Hemisarcoptes malus

1 & 2	Fermate*	3	12	13	27	19	7	4	17	0
3 - 5	Fermate	0	1	3	5	11	14	17	72	0
6 & 7	Lime-sulphur	0	0	0	0	0	0	0	0	1
8	Bordeaux and C.O.C.S.	0	0	0	1	1	2	3	13	6
9	Flotation sulphur	0	0	0	0	0	0	0	0	1
10	Fermate	0	0	0	1	2	2	2	17	11
11	Lime-sulphur	-	-	-	-	1	0	0	0	3
12	Bordeaux and C.O.C.S.	-	-	-	-	3	1	1	8	7
13	Flotation sulphur	-	-	-	-	0	0	0	0	0

* Fermate in 1943 also

(*b*) *Results from the Hiltz-South Yarmouth Orchard*

In 1943 this orchard was divided into two five-acre blocks and since then the north block has been sprayed with bordeaux mixture and fixed copper (C.O.C.S.) and the south block with flotation sulphur. Very few records were made on oystershell scale in these orchards until the fall of 1944 but it is known that the population was low in 1943 and 1944. Most of the observations on the natural control relationships of the oystershell scale in this orchard have been made during the winter months. On the sulphur plot there has been a steady increase in the number of scales and also a continuous increase in the percentage of scales surviving each year. Observation in the summer revealed that *Hemisarcoptes* was active on the copper plot in small numbers but it does not appear to have been as effective a predator upon scales here as in some other orchards. Apparently the mite has greater difficulty in finding living scales than does the parasite when the scales are scarce, as in this plot, and this accounts no doubt for the small numbers of mites found in the winter examinations.

The results of the experiment (Table 4) show clearly that the use of copper sprays will allow natural enemies to keep oystershell scale well under control, while flotation sulphur, as in the Palmer orchard, resulted in a rapid build-up of the scale.

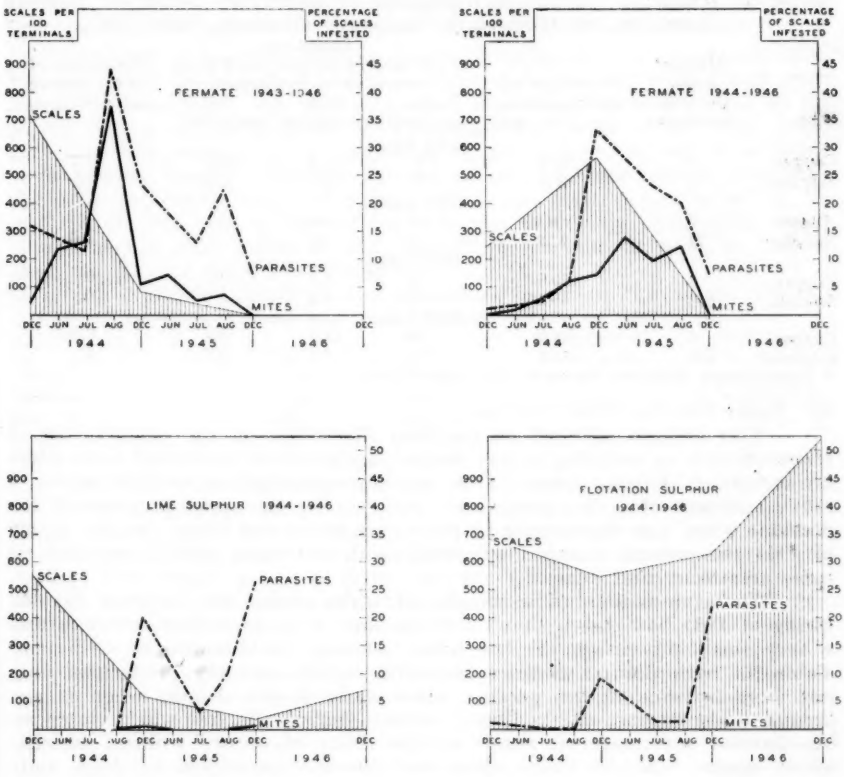

Fig. 1. Effect of spray treatment on the natural control of the oystershell scale in the Palmer orchard.

Table 4. Results of Winter Examinations of Oystershell Scales on Baldwin Trees in the Hiltz-South Yarmouth Orchards, 1944 - 1947.

Plot	Mature* scales per 100 terminals	Percentage of scales surviving (i.e. with eggs)	Percentage of total of current years scales *killed by A. mytilaspidis* 1st. generation	2nd. generation	3rd. generation	Percentage of *healthy* mature scales infested
			1944 Scales			
Copper	?	43.3	?	11.6	25.7	8.0
Sulphur	?	61.8	?	2.4	26.8	Trace
			1945 Scales			
Copper	2	8.6	?	10.8	?	2.9
Sulphur	72	72.2	?	3.8	?	0.0
			1946 Scales			
Copper	3	20.5	3.5	7.7	14.3	0
Sulphur	338	79.1	0.4	0.5	1.9	0
			1947 Scales			
Copper	6	29.0	3.0	12.5	8.0	0.3
Sulphur	458	88.2	0.0	0.3	3.3	0

* These counts made on Baldwins and Gravensteins

(c) Results from the Marshall Orchard

This orchard afforded an excellent illustration of the potentialities of *Hemisarcoptes* in reducing a very heavy population of oystershell scale when no sprays at all were used. This was a commercial orchard in which a heavy outbreak of scales, presumably built up by the spray program of the previous years, was threatening to destroy many of the trees. In the spring of 1945 the orchard changed ownership with the result that it received no spray treatment that year.

An examination of a sample of scales from this orchard in the spring of 1945 had shown that there was only a trace of *Hemisarcoptes* and a very small percentage of *Aphelinus*. During the summer of 1945 (see Table 5) both natural enemies increased rapidly but the predacious mite was more active than the parasite, particularly during August when it was present under almost all the living scales. During the following winter an examination was made to check on the effect of natural control for the whole season. Of the scales which had become established in June, only 5.4 per cent were found to have survived to produce eggs and a large percentage of these scales was attacked by *Hemisarcoptes* and *Aphelinus*.

Table 5. Natural Control of the Oystershell Scale in the Marshall Orchard (Not Sprayed in 1945)

Date examined	No. scales examined	Stage examined	Percentage of living scales infested with *H. malus*	Percentage of scales infested with *A. mytilaspidis*
June 25	2900	1st. instar	0.7	-
July 13	2800	2nd. instar	9.4	11.0
Aug. 28	2800	3rd. instar	94.5	20.3
Dec.	1200	3rd. instar	5.7	11.4

(6) RESULTS OF THE USE OF A BORDEAUX - FERMATE PROGRAM ON THE OYSTERSHELL SCALE POPULATION IN COMMERCIAL ORCHARDS

It was soon evident that a fungicide program of either Fermate or copper sprays with lead arsenate as the insecticide would allow natural control practically to eliminate oystershell scale in from one to three years. The bordeaux - C.O.C.S. treatments gave excellent control of apple scab but caused too much russeting of the fruit to permit their use in commercial

orchards. On the other hand a six-spray program of Fermate afforded inferior control of apple scab but gave excellent finish to the fruit.

In 1945 a bordeaux-Fermate fungicide program (two bordeaux, three Fermate and a final spray of bordeaux mixture, the last five having lead arsenate as the insecticide) was used in a small commercial orchard owned by Mr. R. D. Sutton at Starr's Point. No measure was made of the scale population in this orchard at the beginning of the experiment but it is known to have been heavy. Through the use of the bordeaux-Fermate treatments the scale population was reduced to about one scale per terminal by the autumn of 1945 and by the fall of 1946 was practically eliminated. *Aphelinus* was the more active of the two natural enemies at work in this orchard as may be seen from Table 6.

Table 6. Natural Control of the Oystershell Scale in the Sutton Orchard in 1945. (Bordeaux and Fermate sprays in 1945)

Date examined	No. scales examined	Stage examined	Percentage of living scales infested with *H. malus*	Percentage of scales infested with *A. mytilaspidis*
Aug. 1	1000	2nd. instar	0.0	21.6
Sept. 5	825	3rd. instar	3.6	46.5
Dec.	1000	3rd. instar	10.6	14.5

In 1946 a number of growers in the Annapolis Valley decided to use the bordeaux-Fermate fungicide sprays on portions of their orchards. Mr. G. A. Chase used these materials over extensive blocks of orchard in several parts of the Valley. His orchards were typical as to previous treatment. The results as given below for the Chase orchards are representative of most of the commercial orchards in which the bordeaux-Fermate program was used in 1946 and 1947. In the group of Chase orchards known as the Blomidon Unit the program previous to 1946 consisted of two bordeaux applications followed by five of flotation sulphur. Before the beginning of the new program a survey of oystershell scale showed that this unit had heavy scale populations for the most part and very little natural control. It was quite evident that the extensive use of sulphur sprays had predisposed these orchards to an outbreak of oystershell scale, and in some the scales had already reached destructive proportions. During the summer of 1946 the use of bordeaux and Fermate sprays allowed a marked build-up of *Aphelinus* and in a few cases there was excellent control from *Hemisarcoptes*. In most cases, however, the increase in the natural control agents took place too late in the summer of 1946 to appreciably affect the oystershell scale population but there was every reason to believe that there would be a great reduction during 1947. Two other groups of the Chase orchards, viz. the Canard and the Hillcrest Units, owing to an exceptionally light crop, had received fewer applications of spray than usual in 1945. This was a bordeaux-flotation sulphur schedule in which, for the most part, not more than two sulphur treatments were applied. The sulphur was used in the pink application, in which it has little influence on the parasites, and in the calyx application in which the effect on the first generation of parasites is quite serious. These treatments, however, have only a moderate effect on the second generation of parasites and practically none on the third generation. This, no doubt, accounts for the large numbers of parasites present when the bordeaux-Fermate program was initiated in 1946 in the orchards in these two units. Winter examinations of oystershell scales before and after a season's treatment with bordeaux and Fermate showed no great change in the percentage of scales parasitized by overwintering *Aphelinus* larvae but observations in the orchards revealed that there had been a great reduction in the scale populations.

Data from the orchards in these two Units and from the orchards in the Blomidon Unit are given in table 7.

Table 7. Natural Control of Oystershell Scale in the Chase Orchards in 1945 and 1946. (Bordeaux and Fermate Sprays in both years)

	Percentage of mature scales infested with *A. mytilaspidis* larvae		Percentage of living mature scales infested with *H. malus*	
Unit	Winter of 1945 - 1946	Winter of 1946 - 1947	Winter of 1945 - 1946	Winter of 1946 - 1947
Hillcrest	21.0	18.5	0.2	8.8
Canard	16.7	13.1	1.2	3.3
Blomidon	0.7	12.1	0.0	0.7

(7) NOTES ON THE INFLUENCE OF SOME MISCELLANEOUS SPRAY CHEMICALS ON THE NATURAL CONTROL OF OYSTERSHELL SCALE

Most of the work on oystershell scale has been on the effect of fungicide sprays on *Aphelinus* and *Hemisarcoptes* but a number of experiments and observations have shown that some of the insecticides commonly used in orchards may also have an influence. Most of the insecticides seldom were used alone under field conditions where the mite, the parasite and the oystershell scale were present in sufficient numbers for a reliable comparison. The information given below is based largely on observations in experimental or commercial orchards where the full details of the spray program were known, or upon experiments in which scale-infested twigs were sprayed in the laboratory during the dormant period.

(*a*) *Lead Arsenate*

Lead arsenate has been the standard insecticide used in the copper and Fermate fungicide sprays during the experimental work on the effect of these materials on the natural control of oystershell scale. Since the scale was eliminated by natural means in the blocks treated with these materials, it is obvious that lead arsenate also was relatively innocuous to the mites and the parasites. Furthermore, when infested scales were treated in the laboratory with lead arsenate no noticeable effect on the natural control agents could be detected.

(*b*) *Synthetic Cryolite*

This material was used in only one scale-infested orchard, in a program of two bordeaux and four Fermate sprays. Since both the parasite and the predator were active in the destruction of the scales there is no reason to believe that synthetic cryolite has any detrimental effect on the natural control of oystershell scale. Laboratory tests also confirmed this field observation

(*c*) *DDT*

Where DDT has been used on first instar scales in orchards at the rate of one pound per 100 gallons of spray the destruction of the scales was so great that there was no opportunity to observe its effect on the natural control agents. In one experiment in which a calyx application of this material was used at rates of ¼ and ½ pound per 100 gallons of spray, *Hemisarcoptes* destroyed all the scales which escaped the effect of the DDT. No information was available on its effect on *Aphelinus*.

(*d*) *Dormant Oils*

When dormant applications of petroleum oil in the orchard have been thorough enough to destroy the scale population there has been no opportunity to study their effect on the predacious mite. In the laboratory a 5 per cent dormant oil was found to penetrate beneath the scales and destroy *Hemisarcoptes* among the scale eggs and also to kill the overwintering *Aphelinus* larvae. In one commercial orchard a record of parasitism just before an application of dormant oil and another record a month later showed the oil to have killed the parasite larvae.

(*e*) *Dinitro-o-cresol*

Dinitro-o-cresol, 1¼ pound per 100 gallons of spray is usually incorporated into a 4 per cent dormant oil when used for the control of oystershell scales in Nova Scotia. When scales from an orchard sprayed with this combination were examined a month after treatment *Aphelinus* larvae were found to be dead and somewhat stained. In laboratory tests sodium-dinitro-o-cresylate at ½ per cent of the 17 per cent paste was very destructive to both the parasite and predator under dormant scales.

(*f*) *Nicotine Sulphate*

In one experimental orchard where nicotine sulphate was used in four sprays of a bordeaux-Fermate fungicide program the scale was destroyed mostly by biological means although the nicotine sulphate may have been partially effective. Supplementary tests in the laboratory did not indicate that this material had any adverse effect on the predacious mites or on the overwintering parasite larvae. No information is at hand on its effect on the adult parasites.

(*g*) *Summer Oil*

In a small experiment on several trees on which both the scale and *Hemisarcoptes* were quite abundant, a single application at the rate of ¾ gallon per 100 gallons of spray just as the scale eggs are hatching had very little effect on the predacious mites and was not highly effective against the scales. There was no information on the influence of summer oils on the parasite.

(*h*) *Lethane B* 72 (*Beta, beta-dithiocyanoethyl ether*)

This material was used at the rate of 3 pounds per 100 gallons in a single small experiment where *Hemisarcoptes* was present. In this case it was ineffective against the oystershell scale but was very destructive to the mite.

(8) RELATIVE IMPORTANCE OF THE NATURAL CONTROL FACTORS

During the course of this work it became evident that the most important natural enemies of the oystershell scale in Nova Scotia are the chalcid *Aphelinus mytilaspidis* and the mite *Hemisarcoptes malus*. It happens sometimes that the scales become so crowded on the bark that starvation takes place, or the twig may be destroyed. Considerable mortality of the scales may occur when this happens but very often the limb or even the tree may be severely injured or killed. Extremely low temperatures (below −31°F) were reported by Webster (8) in 1915 to have destroyed the oystershell scale eggs but in the Annapolis Valley there has been no evidence of any control by this means. Tothill (7) and Griswold (3) mention wind and heavy showers, when the scales are crawling, as being of some importance. The chance occurrence of such weather conditions occurring at the proper time could affect the scale population but over a period of years could not, however, be expected to offer sufficient resistance to check the increase of the pest. Birds are also recorded by several writers as feeding upon scales and during the present work some evidence of this has been observed but no case is known where birds effected any appreciable control. Other casual predators have been listed in the literature but in no known case did the author consider them as of primary importance. The only other parasite found on oystershell scale in Nova Scotia was *Chiloneurinus microphagus* (Mayr) which was observed occasionally but was in no case found to be of any apparent economic significance.

Tothill (7) believed *Hemisarcoptes* to be the most important predator of oystershell scale in Eastern Canada in 1919 at a time when only a few apple orchards were sprayed with anything but bordeaux mixture. He rated *Aphelinus* as the only important parasite among the material he exa-

mined in Canada but by inference placed it second to *Hemisarcoptes*. Among the relatively small numbers of orchards which have been examined in detail in Nova Scotia it appears that either species alone can control a heavy outbreak of scale. In cases of large populations of scales where the mite became established first the control has been sensational in one year, whereas, in none of the cases under observation was the parasite able to do this. In the year following such a reduction by the mite it was usual to find very few mites remaining whereas from 10-50 per cent parasitism was common. In commercial orchards in which the practice had been to use some sulphur sprays and in which a change was made to the Bordeaux-Fermate program, the first of the natural enemies to increase in numbers was usually the parasite. Later, as the mites also increased in numbers and during the period in which the greatest destruction of the scales was taking place, it was often difficult to tell which of the two natural enemies was the greater cause of destruction among the scales. No doubt there is some interaction between the mite and the parasite as both are often found under the same scale but there is no reason to believe that the presence of both species interferes with the ultimate destruction of the oystershell scale.

(9) DISCUSSION

The rise of the oystershell scale from a minor to a major problem in sprayed orchards is an excellent example of the indirect or latent effects of spray materials. Although this insect has always been more or less of a pest in Nova Scotian orchards its recent rise to the status of a major pest has coincided with the use of mild sulphur fungicides, particularly flotation sulphur, during the past fifteen years. The special application of dormant oils to alleviate the trouble is an example of the trend toward the use of more sprays and heavier applications with the ever present possibility of the creation of new pest problems. This development of an oystershell scale problem offers strong evidence that pest control programs that largely ignore the biological factors may lead in the future to the creation of new but avoidable problems. In the cases cited the species are capable of building up dense populations in a short time so that the interference of sprays with the natural control may make itself felt in a few years. With species which increase more slowly, but which have greater powers of locomotion and which in small numbers can create havoc to an apple crop, the problem of measuring the influence of sprays on their natural control agents becomes a lengthy and complicated process.

These studies on the influence of sprays on the natural control of oystershell scale have shown that the fungicides used for the control of apple scab differ greatly in their effect on *Hemisarcoptes malus* and *Aphelinus mytilaspidis*. The mild sulphurs such as flotation sulphur have little toxicity to the scale while on the other hand neither the predacious mite nor the parasite is able to survive where these materials have been used. Since *Hemisarcoptes* and *Aphelinus* are the only important biological control agents of oystershell scale in Nova Scotia the continued use of mild sulphur sprays in the bloom period very often leads in a few years to an outbreak of the scale. The action of lime-sulphur is also extremely severe on the natural enemies but since it is moderately toxic to the scale, the latter does not tend to build up as rapidly as with the mild sulphurs. Lime sulphur, however, is now seldom used in the Annapolis Valley owing to its phytocidal properties. Bordeaux mixture (or C.O.C.S.) and Fermate have little if any direct effect on oystershell scale but they are also harmless to its natural enemies, so that, where they are used, even a heavy outbreak of the scale is usually brought under control in one or two years.

The copper sprays are excellent fungicides but when used in the bloom period the resultant russetting of the fruit is too severe, hence these are not recommended for use in commercial orchards.

In Nova Scotia it is possible to control apple scab through the use of Fermate in the bloom period and copper fungicides in the remaining sprays. This program causes very little russetting of the fruit and does not interfere with the natural control of the oystershell scale.

ACKNOWLEDGMENTS

Acknowledgment is made of the hearty co-operation of all members of the staff of the Dominion Entomological Laboratory at Annapolis Royal which has resulted in much more comprehensive records than would otherwise have been possible.

Special acknowledgment is made to Mr. A. D. Pickett, Mr. N. A. Patterson, and Mr. H. T. Stultz who made a comprehensive survey of the Annapolis Valley orchards for oystershell scale in 1942. This survey was of great value in starting the present project.

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NOTES ON THE MENOPONIDAE OF NORTH AMERICA. II.

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Genus **MACHAERILAEMUS** Harrison, 1915

Machaerilaemus Harrison: Parasitology, VII, p. 389 (1915).
Machaerilaemus Harrison: Harrison, Parasitology, IX, p. 60 (1916)
Hirundoecus Ewing: Proc. U. S. N. M., LXXVII, Art. 20, p. 12 (1931).
Machaerilaemus Harrison: Bedford, 18th Rept. Dir. Vet. Serv. and Anim. Ind. Un. S. Africa, p. 377 (1932).
Hirundoecus Ewing: Bedford, *ibid*, p. 380.
Machaerilaemus Harrison: Malcomson, Ann. Entom. Soc. Amer., XXX, p. 53 (1937).
Machaerilaemus Harrison: Clay and Meinertzhagen, Ann. and Mag. Nat. Hist., ser. 11, VII, p. 330 (1941).
Machaerilaemus Harrison: Carriker, Boletin de Entomologia Venezolana, III, p. 65 (1944).

Head broad, twice as wide as long or more; sides of forehead swollen with lateral margins entire. Deep pouchlike antennal fossae in which lie the last segments of the antennae. Dorsal surface of the head with or without a Y shaped suture. Gular plate large, distinct, not fused to the chitinous framework; and with or without a central opening; its lateral margins either with a pair of backward-projecting processes or somewhat swollen anteriorly and without definite processes.

Prothorax broad and winged; prosternal plate distinctive. Mesonotum small and separated from the prothorax by a narrow suture. Third femora without combs or patches of setae.

Abdominal segments broad, armed caudally with single rows of marginal setae and a few lateral spines; paratergal plates without internal thickenings. Sternal plates narrow, each with two irregular rows of setae but without combs or patches of setae. Sternites II-VII each with one to six pairs of short stout spines on the posterolateral angles, the latter being sometimes slightly produced posteriorly.

Male genitalia with an elongate somewhat flat basal plate, free paramera, and bluntly pointed mesomal plate.

Distribution: Apparently confined to the Passeres, where it is uncommon.

Genotype: *Machaerilaemus latifrons* Harrison, 1915.

MACHAERILAEMUS MAESTUM (Kellogg and Chapman, 1899)

(Figs. 9 and 16)

Menopon maestum Kellogg and Chapman: New Mallophaga, III, p. 130, pl. ix, f. 2 (1899); Harrison, Parasitology, IX, p. 40 (1916); Essig, Insects of Western North America, p. 128 (1926); Geist, Ohio Jour. Sci., XXXI, p. 505 (1931).

Machaerilaemus maestum (Kellogg and Chapman): Peters, Bird-Banding, VII, p. 25-27 (1936); Malcomson, Ann. Entom. Soc. Amer., XXX, p. 55 (1937); Clay and Meinertzhagen, Ann. and Mag. Nat. Hist., ser. 11, VII, p. 331-332 (1941); Carriker, Boletin de Entomologia Venezolana, III, p. 71-73 (1944).

Type host: *Zonotrichia coronata* (Pallas), Golden-crowned Sparrow, and *Melospiza melodia samuelis* (Baird), Samuel's Song Sparrow, both collected in California.

In addition to the types, this form has been collected from the hosts and localities from North America as listed:

Pipilo erythrophthalmus erythrophthalmus (Linn.), Red-eyed Towhee—Ohio, N. H., N. Y., and S. C.

Pipilo maculatus oregonus Bell, Oregon Towhee—Oregon.

Poaecetes gramineus gramineus (Gmelin), Eastern Vesper Sparrow—Mich.

Junco hyemalis hyemalis (Linn.), Slate-colored Junco—N. H.

Zonotrichia albicollis (Gmelin), White-throated Sparrow—S. C.

Melospiza melodia melodia (Wilson), Eastern Song Sparrow—N. H.

Carriker has noted that the description and illustrations by Kellogg and Chapman did not agree with specimens from the Oregon Towhee and after examining the type specimens, the writer concurs in Carriker's findings.

MACHAERILAEMUS LATICORPUS (Carriker, 1903)

(Fig. 3)

Menopon laticorpus Carriker: Univ. Studies, Univ. Nebr., III, No. 2, p. 68, pl. vii, f. 5 (1903).

Machaerilaemus laticorpus (Carriker): Harrison, Parasitology, IX, p. 60 (1916); Geist, Ohio Jour. Sci., XXXI, p. 506 (1931); Thompson, Canad. Entom., LXVI, p. 279 (1934); Malcomson, Ann. Entom. Soc. Amer., XXX, p. 55 (1937); Clay and Meinertzhagen, Ann. and Mag. Nat. Hist., ser. 11, VII, p. 331-332 (1941); Carriker, Boletin de Entomologia Venezolana, III, p. 67-68 (1944).

Type host: *Thamnophilus doliatus mexicanus* collected in Costa Rica. North American collections of this species are:

Dolichonyx oryzivorus (Linn.), Bobolink—Ohio.

Passerina cyanea (Linn.), Indigo Bunting—Ohio.

Molothrus ater ater (Boddaert), Eastern Cowbird—Ohio.

Euphagus carolinus (Müller), Rusty Grackle— Quebec, Canada.

Specimens examined in this study were collected off the Antillean Elaenia, *Elaenia martinica martinica*, from St. Lucia, British West Indies.

MACHAERILAEMUS COMPLEXUS Malcomson, 1937

(Fig. 5)

Machaerilaemus complexus Malcomson: Ann. Entom. Soc. Amer., XXX, p. 53 (1937); Clay and Meinertzhagen, Ann. and Mag. Nat. Hist., ser. 11, VII, p. 331-332 (1941).

Type host: *Spizella pusilla pusilla* (Wilson), Eastern Field Sparrow, collected in Pennsylvania.

This species is known only from the type series, a part of which was used for this study.

MACHAERILAEMUS AMERICANUS (Ewing, 1930)

(Figs. 18 and 19)

Hirundoecus americanus Ewing: Proc. U. S. N. M., 77 (20), p. 13-16, f. 6 and 7f (1930).

Machaerilaemus americanus (Ewing): Clay and Meinertzhagen, Ann. and Mag. Nat. Hist., ser. 11, VII, p. 331-332 (1941).

Type host: *Progne subis subis* (Linn.), Purple Martin, collected in New Mexico.

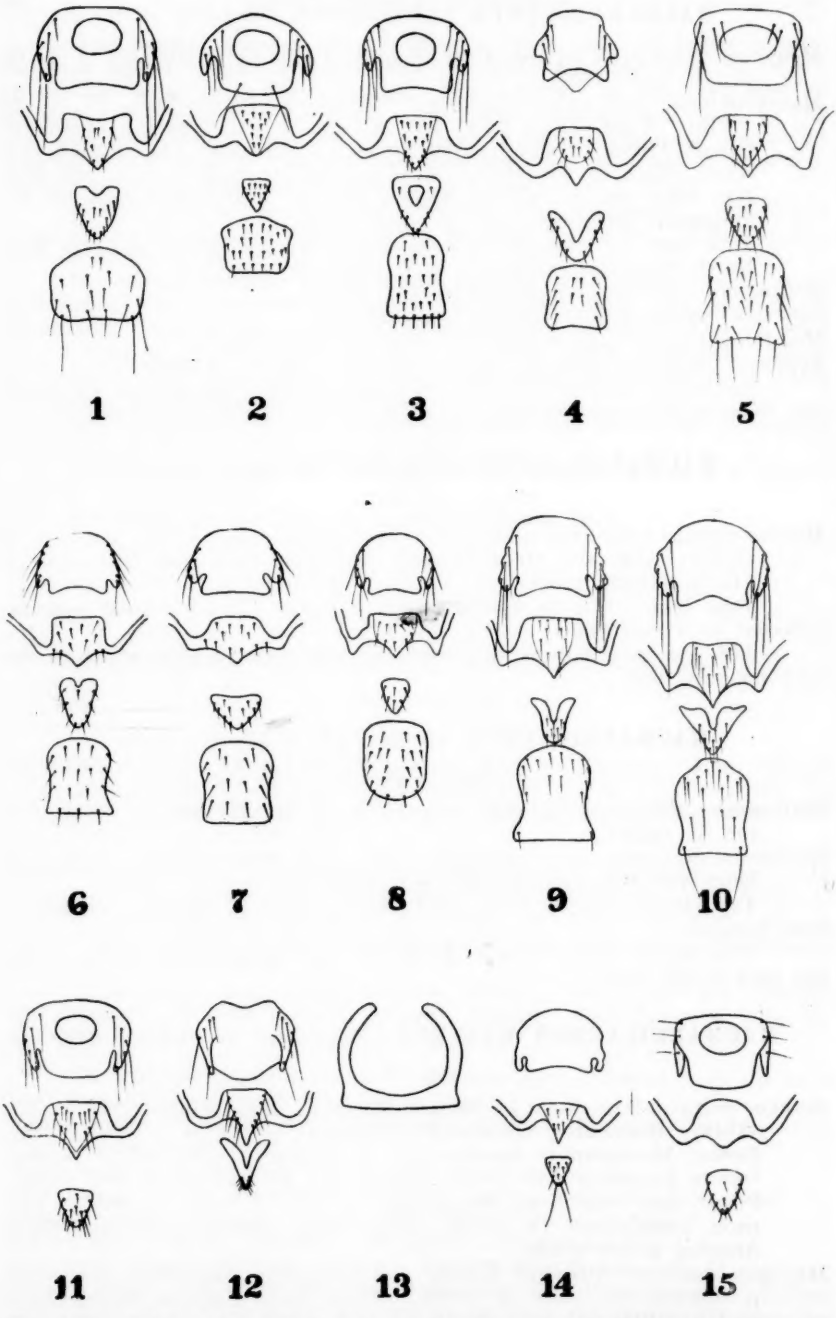
This species is known only from the type specimen, a female, which was used in this study.

MACHAERILAEMUS MALLEUS (Burmeister in Nitzsch, 1818)

(Fig. 13)

Eureum malleus Burmeister in Nitzsch, Germar's Mag. Entom., III, p. 301 (1818); Burmeister, Handbuch d. Entom., II, pt. ii, p. 441 (1838); Denny, Monographia Anoplurorum Britanniae, p. 238 (1842); Giebel, Insecta Epizoa, p. 249 (1874); Piaget, Les Pediculines, p. 608 (1880); Piaget, Les Pediculines, Supplement, p. 139, pl. xv, f. 3 (1885); Harrison, Parasitology, IX, p. 62 (1916); Essig, Insects of Western North America, p. 130 (1926).

Menopon malleus (Nitzsch): Kellogg and Chapman, New Mallophaga, III, p. 133-135, pl. ix, f. 3 (1899); Paine, Rept. Laguna Marine Lab., p. 176 (1914).



Figs. 1-15, Gular region and thoracic sternal plates of *Machaerilaemus* spp.: 1, *M. hawaiiensis* (Kellogg and Chapman); 2, *insignis* Carriker (redrawn); 3, *laticorpus* (Carriker); 4, *atrocephalus* Carrker (redrawn); 5, *complexus* Malcomson; 6, *juninensis* Carriker (redrawn); 7, *robertsi* Carriker (redrawn); 8, *bolivianus* Carriker (redrawn); 9, *maestum* (Kellogg and Chapman); 10, *submaestum* n. sp.; 11, *latifrons* Harrison; 12, *plocei* Bedford (redrawn); 13, *malleus* (Burmeister); 14, *tachuris* Carriker (redrawn); 15, *poecilotis* Carriker (redrawn).

Hirundoecus malleus (Nitzsch): Bedford, 18th Rept. Dir. Vet. Serv. and Anim. Ind. Un. S. Africa, p. 380 (1932).

Machaerilaemus malleus (Nitzsch): Clay and Meinertzhagen, Ann. and Mag. Nat. Hist., ser. 11, VII, p. 331 (1941).

Type host: *Hirundo rustica* Linn.

North American collections of this species from the Cliff Swallow, *Petrochelidon albifrons albifrons* (Rafinesque), taken in California by Kellogg and Paine, were studied by the author.

DISCUSSION

The genus as now defined, is world wide in distribution, and rarely collected. It is a homogeneous one, the species being remarkably similar in most characters, yet there is little difficulty in separating them. The characters which seem to be most stable have been used in a key. An examination of the type specimen of *Menopon hawaiiensis* Kellogg and Chapman shows that it must be included in the genus as well as *M. submaestum* n. sp., *vide infra.*

OTHER SPECIES IN THE GENUS

Machaerilaemus latifrons Harrison, 1915, type host: *Poephila gouldiae.*

Machaerilaemus plocei Bedford, 1920, type host: *Quelea sanguinirostris lathami.*

Machaerilaemus poecilotis Carriker, 1944, type host: *Pogonotricus poecilotis.*

Machaerilaemus insignis Carriker, 1944, type host: *Ochthoeca rufipectoralis tectricialis.*

Machaerilaemus juninensis Carriker, 1944, type host: *Agriornis montana insolens.*

Machaerilaemus robertsi Carriker, 1944, type host: *Cnemarchus rufipennis.*

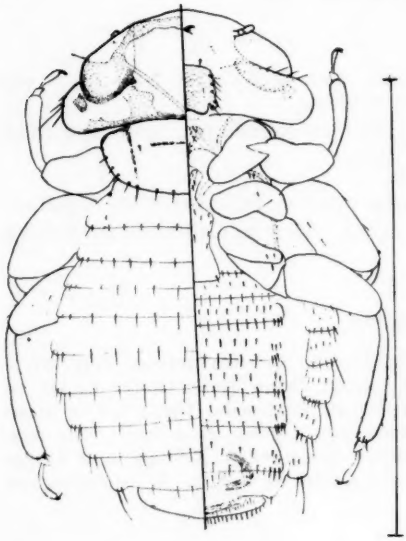
Machaerilaemus bolivianus Carriker, 1944, type host: *Muscisaxicola capistrata borealis.*

Machaerilaemus tachuris Carriker, 1944, type host: *Tachuris rubrigaster grandis.*

Machaerilaemus atrocephalus Carriker, 1944, type host: *Asthenes modesta rostrata.*

Machaerilaemus hawaiiensis (Kellogg and Chapman, 1902) *mihi,* type host: *Chlorodrepanis virens.*

Machaerilaemus submaestum n. sp., type host: "Blue-backed Tanager."



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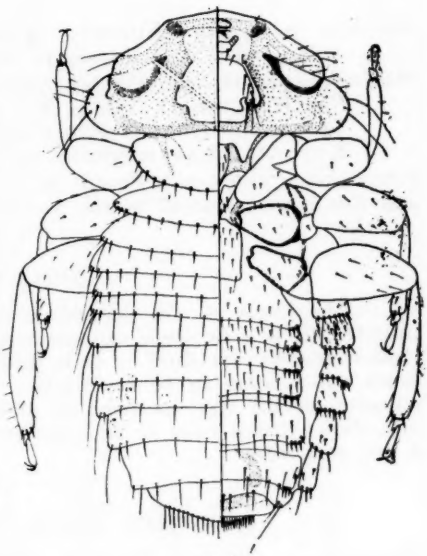

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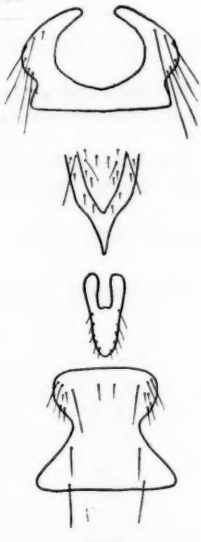

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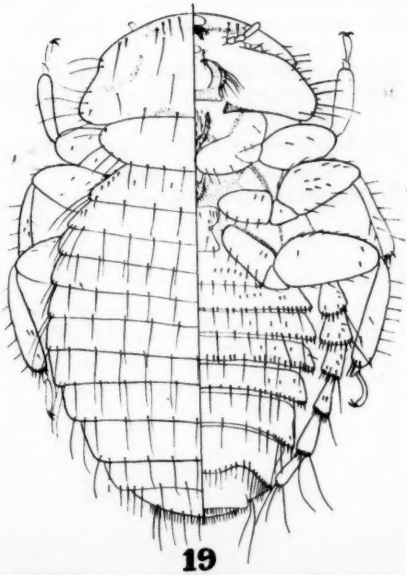

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Fig. 16, *Machaerilaemus maestum* (Kellogg and Chapman), female; 17, *submaestum* n. sp., female; 18, *americanus* (Ewing), gular region and thoracic sternal plates; 19, *americanus* (Ewing), female.

MACHAERILAEMUS SUBMAESTUM n. sp.
(Figs. 10 and 17)

Menopon maestum Kellogg and Chapman: Kellogg and Paine, Entom. News, XXII, p. 23 (1910).

FEMALE: The head is more than twice as broad as long, with the cephalic margin slightly angular. On the dorsal surface of the head is a Y-shaped suture present in several other species of the genus. The gular plate is entire, with posterolateral processes. Five hairs arise from the plate on each lateral margin (fig. 10). The head is more heavily pigmented than in *M. maestum*.

The prothorax is winged, with an interscapular bar not quite reaching the scapulars. Mesothorax and metathorax are alike; viewed dorsally, they resemble abdominal segments. The thoracic sterna are shown in fig. 10. The coxae of the first pair of legs are elongate; the femora, stout and strongly arched; the tibiae, long and tapering at the proximal end.

The abdomen is widest at the fourth segment and dark straw colored with brown transverse bands. The chaetotaxy of the abdomen is shown in fig. 17. Three or four short spines present on the posterolateral angles of the sternites are heavier than in *M. maestum*.

Diagnosis: This form is very closely related to *M. maestum*. Figs. 9 and 10 show ample differences of the gular plates and the thoracic sternal plates of the two species. The chaetotaxies of the head and abdomen and the pigmentation shown in figs. 16 and 17 clearly illustrate further differences.

Type host: "Blue-backed Tanager."

Type locality: Choros, Bolivia.

Type material: Three females, belonging to the Stanford University Natural History Museum.

KEY TO THE SPECIES OF MACHAERILAEMUS

A.	Gular plate with a circular opening in the center	B
	Gular plate open on the cephalic margin	N
	Gular plate without an opening	G
B.	Gular plate with a pair of caudally pointing spinose processes	C
	Gular plate without caudally pointing processes	*complexus*
C.	Dorsal surface of the head with a Y-shaped suture	D
	Dorsal surface of the head without a Y-shaped suture	E
D.	Mesothoracic sternal plate concave on caudal margin, somewhat heart-shaped	*hawaiiensis*
	Mesothoracic sternal plate with a straight or convex caudal margin	*latifrons*
E.	Mesothoracic sternal plate with an opening in the center	*laticorpus*
	Mesothoracic sternal plate solid	F
F.	A pair of hairs on the caudal margin of the gular plate	*insignis*
	Gular plate without hairs on the caudal margin	*poecilotis*
G.	Y-shaped suture on the dorsal surface of the head	I
	No Y-shaped suture on the dorsal surface of the head	H
H.	Gular plate with convex cephalic margin	*atrocephalus*
	Gular plate with concave cephalic margin	*plocei*

I. Posterior margin of the head strongly convex ..... *tachuris*
Posterior margin of the head slightly concave ..... J
J. Only four setae on each lateral margin of the gular plate ..... K
More than four setae on each lateral margin of the gular plate L
K. Three strong pustulated hairs on the temples ..... *bolivianus*
Two strong pustulated hairs on the temples ..... *robertsi*
L. **Metathoracic** sternal plate with four vertical rows of setae and prothoracic sternal plate with setae along lateral margins ..... *juninensis*
Metathoracic and prothoracic sternal plates with scattered setae only ..... M
M. Metathoracic sternal plate with a long seta at each posterolateral angle ..... *submaestum*
Metathoracic sternal plate with a short seta at each posterolateral angle ..... *maestum*
N. Gular plate as in figure 18 ..... *americanus*
Gular plate as in figure 13 ..... *malleus*

PARTICLE SIZE OF DDT WETTABLE POWDERS IN RELATION TO TOXICITY*

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It is generally considered that the smaller the particle size of insecticides applied as solids, the greater is their effectiveness. Smith and Goodhue (1) arrived at this conclusion after a review of the literature. Woodruff and Turner (4) showed that decrease in particle size of DDT wettable powders increased the toxicity of the residues against house flies, and that correspondingly better results were obtained from the residues of smallest particle size in a field test against potato leafhopper and fleabeetles. Steiner *et al.* (2), who have done much work on the effect of DDT particle size on codling moth control, stated that for this purpose the optimum surface mean particle diameter for DDT lies between 2.5 and 5 microns.

The experiments described in this paper were conducted with the aim of obtaining additional information on the relative toxicity of DDT wettable spray powders of different particle size as a result of the processing method.

Test Insects.—The following insects were used in the tests: Potato leafhopper, *Empoasca fabae* (Harr.) reared on scarlet runner, lima and broad bean; diamondback moth, *Plutella maculipennis* (Curt.), reared on cabbage; large milkweed bug, *Oncopeltus fasciatus* (Dall.); green chrysanthemum aphid, *Rhopalosiphum rufomaculatum* Wilson, reared on chrysanthemum; and codling moth, *Carpocapsa pomonella* (L), reared on apple.

Materials.—Three samples of wettable powders, 50% DDT on clay, were prepared by E. I. duPont de Nemours & Co., and supplied through Canadian Industries Ltd. The following data on processing and particle size were furnished by the manufacturer:

Sample	Average mean particle diameter
1 – 50% DDT – Micronized	about 5 microns
2 – 50% DDT – finely pulverized (Hammer milled)	about 15 microns
3 – 50% DDT – coarsely pulverized	about 25 microns

In some tests *Orvus* (32% sodium lauryl sulphate) was added as a wetter.

*Contribution No. 2538, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada.

Methods

All experiments were conducted in the greenhouse or laboratory. The sprays were applied by means of a DeVilbiss compressed air sprayer at a pressure of approximately 20 lb. In most cases the sprayer was held by the operator and the spray applied to either the insect or plant to the point of run-off. The apples used for the codling moth tests were sprayed for a definite length of time in a specially constructed device. Duplicate lots of sprayed apples were artificially weathered by passing them three times at a fixed rate of speed between two sprays of water and allowing them to dry between each passage.

With many of the new insecticides it is difficult to distinguish between direct and residual contact action, and stomach action. For example, if DDT is sprayed on a cabbage plant infested with diamondback moth larvae there will be direct contact action from the material deposited directly on the insect, residual contact action from the particles picked up from the sprayed surface by the insect's appendages, and finally stomach action following ingestion of the treated surface of the plant.

In the tests described in this paper the sprays were applied in three ways and the following terms have been employed to indicate the type of action chiefly involved:

Direct contact action — Sprays applied to insects only and the latter then transferred to clean food.

Residual contact action—Food or other surface sprayed and allowed to dry before untreated insects were placed upon it.

Combined direct and residual contact action — Insects and host plant sprayed at the same time.

Combined residual contact and stomach action — Plant sprayed and allowed to dry before untreated biting insects were placed on it.

Results

The results, which represent summaries of many tests, are discussed under the mode of action resulting from the particular method of applying the insecticide.

Direct Contact Action — A preliminary test was run in which adult milkwed bugs were chilled in vials plunged in ice water, then sprayed for ten seconds in wire screen cages and transferred to clean observation cages. 25 insects were used per cage and 2 cages per treatment. *Orvus* was used in all sprays at the rate of 0.5 lb. per 100 gal. Table 1, giving the kills after 2 and 4 days shows that the micronized sample was the most effective.

Table 1 — *Effect of Particle Size on Direct Contact Action of DDT Against Adult Milkweed Bugs*

DDT — lb. per 100 gal.	Percentage Mortality					
	Micronized		Finely pulverized		Coarsely pulverized	
	2 days	4 days	2 days	4 days	2 days	4 days
4	44	98	18	80	4	46
2	28	88	12	22	2	26

Check — none dead in 2 days; 4% dead in 4 days

Third and fourth instar potato leafhopper nymphs were sprayed on blotting paper in petri dishes and at once transferred to broad bean foliage in small cages. One hundred nymphs were used for each treatment. The results in Table 2, giving the kills after 3 days, although not as consistent as with the milkweed bug, show the marked superiority of the micronized sample, but there was no significant difference between the finely and coarsely pulverized samples.

Table 2 — *Direct Contact Action of DDT Spray Powders of Various Particle Size Against Potato Leafhopper Nymphs*

DDT — lb. per 100 gal.	Percentage Mortality		
	Micronized	Finely pulverized	Coarsely pulverized
0.062	15.0	5.0	6.0
0.25	56.0	8.0	17.0
0.5	100.0	61.0	57.0

Residual Contact Action — Nineteen tests were conducted with the three spray powders against potato leafhopper nymphs by spraying detached portions of broad bean plants and then infesting them with nymphs in the test cages illustrated in Fig. 1.

The results of the tests are summarized in Table 3, which again clearly shows the superiority of the micronized sample.

Fig. 1 — Observation cage used for potato leafhopper nymphs and diamondback moth larvae.

Table 3—*Residual Contact Action of DDT Spray Powders of Various Particle Size Against Potato Leafhopper Nymphs.*

DDT lb. per 100 gal.	Total nymphs	Percentage mortality		
		Micronized	Finely pulverized	Coarsely pulverized
0.007	100	48.0	—	—
0.015	650	70.7	14.6	19.3
0.031	900	91.2	41.3	23.5
0.062	1320	97.8	65.0	52.4
0.125	700	99.5	90.0	85.0
0.25	200	—	100.0	85.0
0.5	100	—	—	100.0

Average mortality in 10 check cages (50 nymphs each) was 7.4%

Combined Direct and Residual Contact Action — Small chrysanthemum plants heavily infested with green chrysanthemum aphid, almost all of which were apterous, were sprayed and mortality counts made after 48 to 72 hours.

The surface of the soil was covered with a plaster of hydrated lime and water to give a surface on which dead fallen aphids could be readily counted and a collar of paper smeared with sticky tree-banding material was placed around the edge of the pot to prevent the escape of living aphids.

In the experiment, summarized in Table 4, approximately 1000 aphids were counted for each individual treatment.

Table 4 — *Combined Direct and Residual Contact Action of DDT Spray Powders of Various Particle Size against Green Chrysanthemum Aphid*

DDT lb. per 100 gal.	Percentage Mortality		
	Micronized	Finely pulverized	Coarsely pulverized
0.125	59.2	4.3	4.9
0.25	85.9	36.8	12.9
0.5	95.8	69.6	37.6
1.0	99.1	91.5	86.5

Combined Residual Contact and Stomach Action — In tests with diamondback moth, unsprayed larvae were placed on sprayed foliage in the jars illustrated in Fig. 1. Only two of the spray powders, the micronized and the finely pulverized, were compared, and *Orvus* was added to all sprays at 0.5 lb. per 100 gal. The results of the tests, summarized in Table 5, indicate that the micronized powder was more effective than the finely pulverized. As was previously pointed out, the relative importance of residual contact versus stomach toxicity in this test could not be determined.

Table 5 — *Residual Contact and Stomach Action of DDT of Various Particle Size on Diamondback Moth Larvae.*

DDT lb. per 100 gal.	Total larvae	Percentage Mortality	
		Micronized	Finely pulverized
0.031	90	52.2	29.8
0.062	90	68.0	38.5
0.125	130	82.7	48.5

Average mortality in check (85 larvae) — 29.2%

Toxicity to Codling Moth Larvae.—In the tests with codling moth larvae DDT apparently functioned both by residual contact toxicity and by ingestion, but extensive investigation over three years proved that the contact action was by far the more important. Because the coarsely ground powder clogged the sprayer it was not included. The other two powders were used at 0.25 lb. DDT per 100 gal.

The day after the fruits were sprayed, half of them were artificially weathered as previously described. Ten codling moth eggs hatching within the next 24 hours were pinned on each fruit in both the weathered and unweathered lots, one day after they were sprayed, and were then incubated at 77°F. and 75 to 85 per cent relative humidity for three days.

The results are given in Table 6. As with most such tests with codling moth larvae, the level of larval establishment varied from day to day. In the case of the fresh deposit, the first three tests on April 9, 23 and 30, indicated that the micronized powder allowed a considerably higher rate of establishment, i.e. was less efficient, than the finely pulverized powder. In the last two tests there was no significant difference between the two powders. The cause of these conflicting results may have been differences in the condition of the apples, as they were showing signs of breakdown toward the end of the tests. No definite conclusion can therefore be drawn concerning the relative toxicity of the fresh deposit.

Where the deposit was artificially weathered by washing the fruit, the micronized material was considerably and consistently more effective in every test. In the absence of residue analyses it is impossible to tell whether this superiority was due to greater tenacity and hence to a greater amount of DDT, or to higher toxicity per unit of residue.

Table 6. *Establishment of Codling Moth Larvae in Apples Sprayed with DDT Powders of Different Particle Size at* 0.25 *lb. DDT per* 100 *Gal.*

Date	No. replicates	Total larvae	Percentage Establishment			
			Micronized		Finely pulverized	
			Fresh dep.	Wash dep.	Fresh dep.	Washed dep.
April 9	3	1086	29.8	37.9	20.0	57.7
23	4	1416	21.0	30.9	8.1	45.6
30	4	1431	22.2	33.8	10.8	51.0
May 7	4	1473	15.4	25.7	16.6	52.3
14	3	835	29.0	48.1	25.1	58.5
Average			23.5	35.3	16.1	53.1

DISCUSSION

To investigate properly the problem of particle size in DDT spray powders would require very extensive work. When two materials of widely different degrees of hardness are ground together, the average particle size of any one component can scarcely be expected to be the same as that of the mixture. Weisser and Gooden (3) found that when DDT was ground with a mineral diluent in a hammer mill and the mixture separated by wet sieving into fractions of different ranges of particle size, the proportion of DDT in the different fractions varied considerably. They found that the percentage of DDT in a fraction of any given particle size also varied with the particular diluent used. Although these workers did not investigate the point, it is possible that the actual DDT particle size may also vary among mixtures of the same average particle size but ground by different processes, e.g. micronizer or hammer mill.

As various investigators have pointed out, the average particle size is a very misleading value. If the range of particle size within the sample is considerable, the greater proportion by mass may consist of particles much above this value.

For these reasons the present experiments should not be considered as comparisons of DDT of the exact particle size given for the spray powders used. Nor are they valid comparisons of micronizing versus hammer-milling of DDT spray powder, because the particle size produced by either process may vary considerably, although micronizing usually gives the finer product. They do show that particle size greatly influences the toxicity of DDT spray powders and that the finer powders, at least down to the neighbourhood of 5 microns are more effective under the conditions of the tests. The relative difference in toxicity was greater by direct contact action than when only stomach and residual contact action were involved. This increased efficiency could result from either a greater deposit or from greater toxicity per unit weight. As the actual deposit was not determined in these experiments the relative importance of these factors is unknown.

Under field conditions where residual toxicity is very important, a DDT spray deposit may lose efficiency through mechanical removal by rain, chemical decomposition by ultraviolet light, or absorption into the waxes of the plant cuticle. Particle size may conceivably influence each of these processes to a different degree or in a different direction. For these reasons, only field experiments can give the ultimate answer to the question of ideal particle size of DDT spray powders. There is reason to believe, however, that a powder with 5 micron particles is generally more efficient than one with particles of 15 microns or higher.

SUMMARY

DDT spray powders of three different average particle sizes were tested in the laboratory and greenhouse for direct or residual contact toxi-

city or combined contact and stomach toxicity against five species of insects. In most cases the finest powder (approximately 5 microns average particle diameter) was most effective.

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OBSERVATIONS ON THE EMERGENCE OF *PHOROCERA HAMATA* A. AND W. (*TACHINIDAE*) FROM SAWFLY COCOONS*

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The literature dealing with the methods by which the larvae and adults of tachinid parasites escape from sawfly cocoons indicates in certain cases that only circumstantial evidence is available concerning the formation of the exit hole in nature. Among these parasites a large number leave their hosts while the sawflies are in the larval stages. The larvae make their escape as mature maggots through a hole gnawed in the soft host integument. A few species, however, continue to develop within the host after the host cocoon has been formed. Some of these cut through the cocoon as mature larvae and later pupate in a suitable medium, while others form their puparial cases within the host cocoons, the adults later escaping from both the puparial cases and from the sawfly cocoons. The only escape mechanism possessed by an adult tachinid fly consists of the alternate expansion and contraction of the ptilinum against the surrounding wall. Since the cocoon is usually quite tough and leathery it is essential that some provision be made in advance to enable the adult to escape. This seemed to occur with adults of *Phorocera hamata* A. and W. which emerge from their puparia within the host cocoon and then escape from the cocoon proper, leaving a characteristic round cap which appears to have been cut (Fig. 1, C). The method of formation of this cap has been the subject of discussion by several authors.

The hypothesis that the opening through which the adult fly makes its escape is prepared by the mature parasite larva before its pupation was advanced by Prell (1924) who described the emergence of *Diplostichus janithrix* Htg. from the cocoon of *Diprion pini* L. The same conclusion was stated by Robbins (1927) after describing the emergence of this parasite. In addition he draws attention to the slight ridges of material resembling fine sawdust found on the inner wall of the cocoon which are similar to those found on the edges of emergence holes made by sawflies. DeFluiter (1932) discusses three possibilities in the formation of the characteristic lids found on cocoons of *D. pini* parasitized by *Diplostichus tenthredinum* B.B. and by dissection studies disproves the formation of the inside grooves by either the sawfly larva or the parasite imago. The elimination of these two possibilities led him to accept the conclusion that the mature parasite larva must preform the lid.

*Contribution No. 2524, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada.

During the course of studies on the biological control of several species of sawflies, field collections of *Neodiprion lecontei* Fitch and *Neodiprion banksianae* Rob. were found to be rather heavily parasitized by the tachinid, *P. hamata*. It was observed on rearing this material in the laboratory that adult parasites emerged from the host cocoons through circular holes similar to those made by the sawflies (Fig. 1, D) except that they were somewhat smaller and that the lids remained attached to the cocoons by means of a small hinge. A microscopic examination of unemerged cocoons containing puparia of the parasite revealed the presence of an internal groove

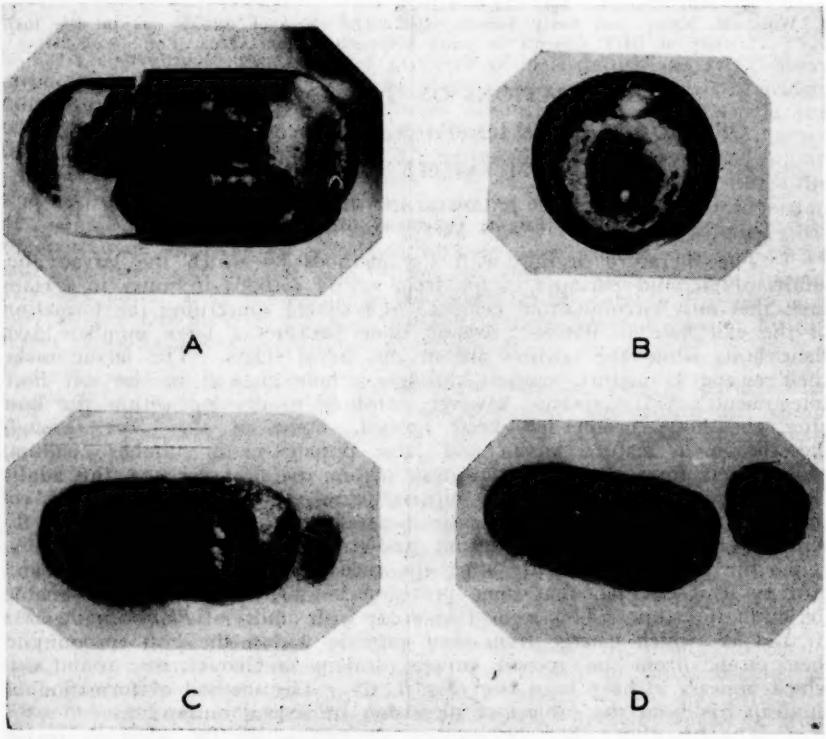

Figure 1. Photomicrographs illustrating methods of emergence of *P. hamata* and *N. lecontei*.

(A) Grooved gelatin capsule showing puparium and host exuviae.
(B) View of grooved end of capsule.
(C) Sawfly cocoon showing exit hole made by *P. hamata*.
(D) Sawfly cocoon showing exit hole made by *N. lecontei*.

forming the outline corresponding to the emergence hole. This groove was absent in cocoons containing immature parasites and it seemed certain therefore that it was made not by the sawfly but by the parasite just before pupation. Since it is impossible to make direct observations through the opaque wall of the cocoon, sawfly larvae containing immature parasites were transferred to transparent gelatin capsules measuring 5 by 15 mm. In this way continuous observations could be made. The presence and position of the parasites in the host larvae was easily detected by the characteristic brown respiratory funnels immediately below the host integument.

The mature parasite larva leaves the host remains by gnawing a hole in the integument with the mouth hooks and immediately migrates to either end of the capsule. In this position the larva braces its posterior abdominal segments against the side of the capsule. Muscular contraction in the posterior region forces the body contents anteriorly causing an expansion which brings the mouth hooks into close contact with the gelatin surface. By a continuous rasping action a circular groove corresponding to the outline of the typical lids found in parasitized cocoons is cut around the end of the capsule (Fig. 1, B). In the majority of cases the deeply grooved circle is of uniform width. Some capsules, however, show a distinct narrowing of a section of the groove which in the cocoon often forms a hinge. The slight ridge of material resembling fine sawdust that becomes dampened so that the particles coalesce as mentioned by Robbins (loc. cit.) in sawfly cocoons is formed around the groove in the capsules by the rasping action of the larval mouth hooks. When the circular groove is completed the larva withdraws to the centre of the capsule where it forms its puparium beside the host remains (Fig. 1, A). The anterior end of the puparium is directed toward the cap and the emerging adult is thus oriented in the direction of the ultimate exit hole. As the flies emerged they were observed in the act of expanding and contracting the ptilinum against the grooved end of the capsule. Owing to the inability of the larvae to cut the grooves to a sufficient and uniform depth in the gelatin softened by the humidity of the incubator, only one parasite of a number observed was able to effect its escape.

SUMMARY

The method employed by mature larvae of the tachinid parasite *P. hamata* to permit escape of the adult flies from sawfly cocoons has been investigated. By transferring parasitized sawfly larvae to gelatin capsules, it was definitely shown that the groove forming the characteristic cap-like lid left on the cocoon by emerging adult parasites was formed by the action of the mouth hooks of the mature larvae just before pupation. Thus, it has been demonstrated that the emergence hole formed by some tachinid parasites which complete their development in the host cocoon is prepared by the parasite larva, confirming the deductions made by Prell, Robbins, DeFluiter and others.

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REPORT ON THE ACTIVITIES OF THE MONTREAL BRANCH ENTOMOLOGICAL SOCIETY OF ONTARIO

This is the 75th Annual Report of the Montreal Branch of our Society and is thus another milestone in its history. We celebrated our 50th Anniversary in 1923 and since then another 25 years of entomological effort and activity have gone by.

Several of our members who were active at the time of this last Anniversary have since passed along; of these, special mention should be made of the following: Mr. A. F. Winn, who died in 1935 after being a member for 47 years and Mr. J. W. Buckle, who died in 1947 after being a member for over 25 years.

But we are, however indeed very fortunate in having as our President, Mr. G. A. Moore, who has been an active and enthusiastic member of the Society for 52 years and to have as a member of our Council, Mr. G. Chagnon, an active member of our Branch for 50 years.

In order to celebrate this event we have invited our Parent Society to hold its Annual Meeting, the 85th, in Montreal next November and we will make this the occasion of a joint celebration. A committee has been formed and is now making the necessary arrangements.

During the past year we held eight meetings, six in the Lyman Room, Redpath Museum, McGill University and one each in the Entomological Laboratory of the University of Montreal and Macdonald College with a total attendance of 81 members and 19 visitors or an average of over 12 for each meeting.

Three new members were elected to our Branch during the year.

The following 14 papers and talks were given during the year:—

Presidential Address

1. The Insect as an Organism — Geo. A. Moore
2. On Pests of Apple Orchards – 1947 — A. A. Beaulieu
3. Two weeks spent in Maryland in June 1947 — Geo. A. Moore
4. The discovery locally of the European Earwig—*Forficula auricularia* — H. A. U. Monro
5. Review of the book "An Explorer Comes Home" by Roy Chapman Andrews — Geo. A. Moore
6. Montreal to Key West, Florida and return – a series of Kodachrome slides — Dr. G. H. Fisk
7. Insect Galls — G. Chagnon
8. Insect Whereabouts — Rev. Father O. Fournier
9. Remarks on a visit to the meetings of the Entomological Section of the Amer. Assc. for the Advancement of Science, Chicago — H. A. U. Monro
10. Review of the book "Fleas of Western North America" by C. A. Hubbard — Geo. A. Moore
11. A report on the Collections of the late J. W. Buckle — Geo. A. Moore
12. The Durra Stem Borer – *Sesamia cretica* Led. — H. A. U. Monro
13. Some remarks on an exhibit of a series of microscopic slides used in teaching in the Dept. of Parasitology, Macdonald College — Dr. E. Munroe
14. The Insect Laboratory–Sault Ste Marie, Ont. — G. A. Bradley

The following were elected officers for the 1948-1949 season:—

President:—Mr. Geo. A. Moore
Vice-Pres:—Rev. Father O. Fournier
Sec'y-Treas.:—Mr. A. C. Sheppard
Council:—Dr. G. H. Fisk, Prof. E. R. Bellemare, Mr. H. A. U. Monro
Dr. E. Munroe, Mr. J. B. Maltais and Mr. A. A. Beaulieu.

Respectfully submitted,
A. C. Sheppard, Secretary.

NOTE ON THE DISAPPEARANCE OF DEAD GRASSHOPPERS FROM SITES OF APPLICATION OF CONTROL MEASURES[1]

BY L. G. PUTNAM
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For some years it has been evident to workers conducting research on grasshopper control methods that those dead grasshoppers which can be found at the scene of application of a control measure do not necessarily represent all the grasshoppers which have succumbed to the treatment. Often, dismembered remains are considerably in evidence and usually only the more resistant parts, such as head capsules, remain to be found. It is reasonable to suppose that many of the dead bodies of grasshoppers may disappear entirely, before sufficient time has elapsed for the final observations on the treatment. It is important, therefore, in relation to the appraisal of the efficiency of control measures in the field, such as baiting, to know to what extent this is true. It is particularly important in the study of baits because, where arsenites are used, at least three days may be required for the poison to take full effect after ingestion and before the appraisal can be made. Meanwhile, a considerable period of time has elapsed during which grasshoppers that died 1 or 2 days after feeding could be removed. Under these circumstances it would obviously be erroneous in appraising the results, to take into consideration only the counts or estimates of numbers of dead on the ground, particularly if compared with the estimated population prior to baiting.

In order to determine whether or not natural agents do remove appreciable numbers of dead grasshoppers within a short time, the author killed grasshopper nymphs in cyanide gas and placed known numbers of them on square-yard quadrats in various situations. All those that could be recovered after 48 hours were counted. Brief accounts of the experiments, and their results, are presented herewith.

(1) Lac du Bois District, near Kamloops, British Columbia, 24-26 June, 1945. On dry upland range 193 dead nymphs of third to fifth instar *Melanoplus mexicanus mexicanus* Sauss. were placed on a square-yard quadrat. After 24 hours, a casual inspection indicated a scarcity of the dead nymphs, and after 48 hours, only 11 could be recovered, including head capsules.

(2) Field near Swift Current, Saskatchewan, 6-8 July, 1945. On wheat stubble from 1944 and green weeds on sandy soil. Fifty dead nymphs per square yard, consisting of mixed *Melanoplus* spp. in second to fourth instars, were placed on four square-yard quadrats. The following numbers were recovered from individual quadrats after 48 hours: Quadrat I, nil; Quadrat II, 10; Quadrat III, 3; Quadrat IV, 9; average number recovered, 5.5 per square yard or 11 per cent. Many of those recovered were more or less disintegrated. Care was taken to avoid duplication of counts as a result of dismemberment. A general observation was to the effect that even 50 dead nymphs per square yard are remarkably inconspicuous and would have required close search for complete recovery even immediately after spreading.

These experiments were conducted merely to establish the fact, and no actual observations were made to determine what natural agents were responsible for the disappearance of the bodies of the grasshoppers. However, it was noted that a number of insects were present which might have been important in this respect. Grasshoppers were of course present and grasshoppers are cannibalistic in at least some circumstances. Crickets

[1]Contribution No. 2519. Division of Entomology, Science Service, Department of Agriculture of Canada.

(*Gryllus assimilis* Fab.) were present and these insects are frequently seen feeding on dead grasshoppers. Ants were very numerous, and seemed capable of patrolling every square inch of the ground daily. The author has observed ants dragging dead grasshoppers away by the antennae, although not in this experiment. Carabidae of genera such as *Bembidion, Poecilus, Carabus* and *Calosoma* all seemed to scour the surface of the soil constantly. Silphidae (*Necrophorus* and *Silpha* spp.) were ever-present and Tenebrionidae (*Eleodes* spp.) were occasionally seen. Mammals, chiefly mice, skunks and ground-squirrels, and birds, must also be included among the potential natural agents which could remove dead grasshoppers.

Some objections which might be taken to the technique adopted for this experiment are: (1) The quadrats containing the dead nymphs were only small 'islands' in an ecological 'sea'. Ants, for example, might be capable of exploiting such areas from a considerable distance. (2) In other typical situations, such as heavier soil or more recently cultivated land, the foraging insect forms might be fewer in number and less varied in kind. Further experiments have not been carried out in such places. (3) Evidence has been obtained recently which indicates that where a quick-acting insecticide is applied over a large area populated with adult grasshoppers, counts of dead, if made within 24 hours of the application, can yield useful and probably accurate information.

In view of the evidence presented, and notwithstanding the objections which could be made, it is clear that in any grasshopper control experiment involving the counting or estimation of dead in the field, the possibility of the removal of many dead before final observations can be properly made must be taken into consideration. In experiments using the slower stomach poisons, research workers have tended to reject their own results obtained by observations of dead on the ground or to avoid the method entirely. Estimates of living populations alone, before and after treatment, can be made with relative accuracy provided the treatment is extensive enough to minimize the factor of migration as a source of error.

SOME FACTORS INFLUENCING DIAPAUSE

F. J. SIMMONDS

Commonwealth Bureau of Biological Control

(1) INTROUCTION

In a previous paper (Simmonds 1946) a curious factor affecting diapause in insects was recorded. In two species of parasitic Hymenoptera the age of the parent female at the time of oviposition has a marked effect on the tendency of the resulting larva to enter a state of diapause when full-grown. The older the female at the time of oviposition the greater is the chance that an egg will produce a larva entering diapause. In a second paper (Simmonds 1948) this maternal influence on the tendencies of her progeny to enter diapause was investigated further. Some general conclusions were drawn as to the nature of diapause, and the experiments were considered in the light of the various theories put forward to explain the phenomenon. In brief it was concluded that the underlying cause of diapause is the occurrence of a physiological disturbance at some stage in the life-history. This may take place much earlier in development than at the time at which diapause occurs, or even when the eggs are being formed, when it is then caused by peculiarities of maternal physiology. These physiological disturbances may be of a varied nature, and thus as has been put forward in the various theories explaining the phenomenon, diapause may actually be due in individual species to lack of adequate nutrition, to humidity and water relationships, to temperature changes, hormonal deficiencies, or possibly to underlying genetical causes reacting peculiarly to the

environment. Fundamentally, however, diapause is due to some physiological maladjustment during development, and it is not an adaptive character enabling a species to surive a period unfavourable to further growth, but a pathological state due to previous environmental or intrinsic influences. That this arrest in development often coincides with a period when the environment is unfavourable is due to the initiation of physiological disturbances by these conditions. That this causes a physiological state in the insect well suited to withstand a prolonged unfavourable period is usually fortuitous, and in many species individuals enter a state of diapause at a time when the environment is favourable to further growth and further increase of the species.

It seemed probable that in some species an alteration in the food of developing larvae might influence the tendency for them to enter diapause, since a different diet would be expected to affect the developmental physiology. Also since the effect of maternal physiology on the incidence of diapause in her progeny has been shown, it was thought possible that the type of development undergone by the female, whether direct or with an intervening period of diapause might affect the prevalence of diapause in her progeny through influences initiated during ovarian development.

(2) EXPERIMENTAL

In the previous work on this subject cited above single isolated females of *Cryptus inornatus* Pratt of known developmental history were used. In the present experiments a number of females with similar developmental history emerging at approximately the same time (within a few days) were kept in a large cage (wooden, 14" x 10" x 10" with cheesecloth top, back and sides, and a xylonite front) well supplied with wet cottonwool and raisins. With these females a number of similar males were placed; the females were not mated individually. Three such cages were set up containing respectively, females from larval material not in a true state of diapause collected in the field and stored for 8 months at 35-40°F, females from similarly collected material but which was in a definite state of diapause, and females from larvae without arrested development bred from the above field-collected material not in diapause. (For the occurrence of two types of overwintering cocoons in the field see Simmonds 1948). As before all these experiments were conducted at a constant temperature of 75°F and a fairly constant humidity of about 70% R.H.

A number of cocoons each containing a hibernating larva of *Loxostege sticticalis* L. was placed in each cage and removed after 24 hours, fresh cocoons being put in. These cocoons were dissected. The parasite eggs, laid within the cocoon near the paralysed host larva, were removed and then placed singly on coddled hosts (time and temperature of coddling dependent on the species of host used.) These host larvae were placed individually with their single parasite egg, in a small shell vial (1½" x ¼" internal diameter) and a cotton-wool plug was pushed down into the tube so that the host larva and parasite egg were enclosed in as small a space as possible. Each day the total eggs obtained from each cage were divided approximately equally into several lots and each lot used with one type of host. The hosts used were:—(a) a single *Loxostege* larva, (b) two *Loxostege* larvae, (c) a single larva of the European corn borer *Pyrausta nubilalis* Hbn., (d) a single larva of the codling moth, *Cydia pomonella* L. At the beginning of the experiment several lots of eggs were used with a single larva of *Ephestia kühniella* Zell. but owing to extremely high mortality these were discontinued, though a few progeny were obtained. Mortality of larvae was also very high when *Cydia* larvae were used as hosts and the results obtained from this group are of little value. However, those from parasite larvae fed on a single and on two *Loxostege* larvae gave interesting results as to the effect of *quantity* of food on development, and those experiments where *Pyrausta* larvae were used as hosts show the effect of different *quality* of food. Since each day's eggs from each cage were kept separate, the effect of aging of the cage of females

as a whole can be seen. However, since the females in each cage were not of identical age the results would not be expected to be as clear cut as when individual females were used. Hence the point is not stressed here. The interaction of the two factors:--differences in the developmental history of the parent female and differences in larval diet may be seen from these results.

(3) RESULTS

Each day the eggs from each cage were divided, as stated above,, between several types of host material. The origin of each egg and the food supplied for the subsequent larva were recorded, as was the latter's ultimate fate:—dead, full-grown larva in diapause, or emergent without diapause, together in the last eventuality with the sex and developmental time of the adult. These results were grouped according to the cage from which the eggs were obtained and the type of host on which the larvae had fed, irrespective of the age of the parent females when the eggs were laid. These are given in Table 1. The results with *Cydia* larvae as hosts are omitted owing to the high mortality noted above. The effect of the two factors, origin of parent female and larval diet, may at first conveniently be considered separately.

A. Effect of differences in the type of development of parent female.

From Table I it is strikingly apparent that progeny from those females which in development passed through a period of true diapause show a far lower incidence of diapause than do those from parents which developed without larval diapause, whether the latter were collected as larvae in the field or bred in the laboratory. This is noticeable whichever type of larval food is considered. In these experiments there is no significant difference in this regard between females from field-collected larvae (which have been subjected for 8 months to a slowing of development due to low temperatures) and those bred in the laboratory (F_1 from this field-collected material, which developed without any arrest in development, either in the nature of diapause or of a slowing down due to low temperature). Thus it is obvious that since the larvae in each food group received exactly the same treatment regardless of the type of female from which the eggs originated, this tendency for direct development shown by progeny of females which were reared from larvae in diapause is due to some peculiarities of the eggs when laid. Now it is reasonable to assume that during larval diapause the development and maturation of the ovaries may proceed at a different relative speed from that occcurring during direct development, that consequently eggs from the two types of females will have had a different developmental physiology, and may therefore differ considerably in their potentialities for producing larvae entering a state of diapause. This is confirmed to a certain extent by a consideraton of the oviposition rate curves for the two types of field-collected material. In Table II are shown, totalled for each 10-day age interval, the numbers of eggs laid throughout life by two groups of females, one in which larval development in the field was arrested in the autumn simply by the lower temperatures, and the second in which a true state of diapause occcurred. Since the number of females in each group was not the same, the oviposition for each 10-day period has been expressed as a percentage of the total oviposition. It is seen that those females resulting from larvae in true diapause laid a greater proportion of their eggs in the first part of their life, whereas those from larvae whose development in the field was arrested simply by the lower autumn temperatures reached their peak of oviposition in the 3rd and 4th 10-day periods. This indicates that females emerge with the ovaries more mature when a true state of diapause has occurred in the life-history.

Thus it is seen that the occurrence of a period of true diapause during the development of an individual female has a definite effect on the tendency of her progeny to enter a state of diapause, and that this is probably correlated with differing rates of maturation of the ovaries.

B. Effect of differences in larval food.

The effect of the quantity and quality of larval food on diapause is clearly shown in Table 1. Consider first the progeny of those females from field-collected larvae not in true diapause. When each parasite larva was provided with a single *Loxostege* larva as food 11.3% of the individuals surviving at the end of cocoon formation entered a state of diapause. When two *Loxostege* larvae were provided this figure was little higher (13.6%). However, when the *quality* of the food was altered and a single *Pyrausta* larva supplied, 29.0% of the living progeny entered diapause.

When the parent females had themselves passed through a state of diapause during development the relationships of the incidence of diapause in the three larval food groups were:—single *Loxostege* larva 4.7%, 2 *Loxostege* larvae 1.3%, *Pyrausta* larva 14.3%, again showing a considerable increase when the quality of the food was changed. A similar effect is shown with laboratory-bred females without an arrest in their development:—Single *Loxostege* larva 12.0%, 2 *Loxostege* larvae 18.9%, *Pyrausta* larva 30.7%.

Two further interesting points are brought out in Table I. First, that the mortality of parasites feeding on single *Loxostege* and *Pyrausta* larvae is similar indicating that *Pyrausta* is in general a suitable host for *Cryptus* and that the difference in quality of larval food finds expression in an alteration in the incidence of diapause, not in a change of mortality.

Second, it is seen that the developmental time of the emergent progeny is consistently longer in all three groups when two *Loxostege* larvae are used as larval food, and the effect is even more pronounced when a *Pyrausta* larva is used as host material. When two *Loxostege* larvae are provided the feeding parasite larva has excess food and continues feeding longer to attain on the average a larger size than it would had only a single host larva been present. The resulting adults are also larger. This has very little, though perhaps some, correlated effect on the incidence of diapause. However the correlation between incidence of diapause and length of developmental time shown in the previous paper (Simmonds 1947) is strikingly evident when comparing the two series where (1) a single *Loxostege* larva and (2) a single *Pyrausta* larva is provided as food for the developing parasite. The pertinent figures from Table I are given here:—

Origin of parent female	Percentage of diapause occurring in progeny		Developmental time of emergent progeny*	
	Loxostege larva as host	*Pyrausta* larva as host	*Loxostege* larva as host	*Pyrausta* larva as host
1. Field material not in diapause	11.3	29.0	18.95	23.79
2. Field material in true diapause	4.7	14.3	18.77	24.09
3. Laboratory bred material not in diapause (F, from 1)	12.0	30.7	19.40	23.69

*This is the mean of the average developmental time of the total males and that of the total females in each group.

With the progeny of each type of female the close correlation between increased incidence of diapause and increased developmental time of emergents where a *Pyrausta* larva instead of that of *Loxostege* is used as host is clear.

The question of the suitability of different species as hosts for entomophagous parasites has been dealt with previously (Simmonds 1944), and this alteration of the incidence of diapause by changing from a natural to an "un-

natural" host in the laboratory is another aspect of this general subject that might prove of value in the propagation of insect parasites for storage or shipment where a high proportion of individuals in diapause would be an asset.

When two *Loxostege* larvae are provided for each developing parasite larval mortality is decreased. This may be attributed to the fact that when two host larvae are present in the vial the parasite larva on hatching has an increased chance of contact with a suitable area of host larval skin. One further point of interest is brought out in Table I. With *Cryptus* there appears to be no significant alteration of sex ratio of the emergent progeny when a different quantity or quality of food is supplied for the developing parasite larva. This does not actually seem surprising, but contrasts with the suggestion put forward by a number of authors that larger hosts produce a greater percentage of female progeny than do smaller ones.

(4) CONCLUSIONS

From these experiments two facts are apparent. The developmental history of the parent female has a marked effect on the incidence of diapause in her progeny and the quality of larval food also has an influence in this regard.

Both these factors might be expected to have an effect on the physiology of development of the parasite larva; in the former case by some influence transmitted through the egg. This maternal influence is seen to affect the numbers of progeny entering diapause whatever the subsequent food provided for the developing parasite larva. This is not due to any genetical difference between the groups of females used, since these were selected at random from emergents from field material collected at the same time and place, or else from females bred in the laboratory from this field material, and similar to it genetically.

The type of food on which a larva is feeding would undoubtedly affect its developmental physiology directly, and it is to be expected that when fed on an "unnatural host", even one suitable for laboratory breeding, the development of the parasite larva might be abnormal enough to entail a subsequent period of diapause, even though not sufficiently so to cause a heavy mortality. Correlated with this there is, as might be expected, an increase in the developmental time of those individuals emerging without diapause, indicating that in these individuals some physiological disturbance occurred which slowed up development but which was insufficient to induce a state of diapause.

Thus these experiments give further support to the conclusion that any physiological disturbance or peculiarity which, though insufficient to entail death, is of sufficient magnitude to cause maladjustments in developmental processes, will find expression in an increase in developmental time, or if of a more serious nature, in the assumption of a state of diapause.

(5) REFERENCES

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Variations in development of larvae of *Cryptus inornatus* due to differences in development of parent female and to differences in larval diet.

Origin of parent female	Coddled larvae provided as food for parasite larva																							
	Single *Loxostege* larva							Two *Loxostege* larvae								Single *Pyrausta* larva								
	Total eggs	Died	Emergents ♂	Emergents ♀	Larvae in Diapause	Developmental time in days ♂	Developmental time in days ♀	Total eggs	Died	Emergents ♂	Emergents ♀	Larvae in diapause	Developmental time in days ♂	Developmental time in days ♀		Total eggs	Died	Emergents ♂	Emergents ♀	Larvae in diapause	Developmental time ♂	Developmental time ♀		
From field collected material, larvae developing without true diapause	165	68	64	22	11	18.09	19.82 (18.95)	181	56	80	28	17	19.32	21.18 (20.25)		188	81	52	24	31	22.75	24.83 (23.79)		
Percentages*		41.2		25.6	11.3				30.9		25.9	13.6					43.1		31.6	29.0				
From field collected material larvae in diapause.	165	79	64	18	4	18.27	19.28 (18.77)	123	47	64	11	1	18.84	19.82 (19.33)		127	71	38	10	8	23.08	25.10 (24.09)		
Percentages*		47.9		220	4.7				38.2		14.7	1.3					55.9		20.8	14.3				
Material bred in laboratory, no diapause in development (F1 from above field material not showing diapause.	175	83	61	20	11	19.11	19.70 (19.40)	177	66	56	34	21	18.89	21.24 (20.06)		180	79	44	26	31	22.98	24.41 (23.69)		
Percentages*		47.4		24.7	12.10				37.3		37.8	18.9					43.9		37.1	30.7				

*In this line are given the percentages:—1. Died; total mortality as percentage of total eggs.
2. Percentage of females in individuals developing without diapause.
3. Percentage of total living full-grown larvae going into diapause.

TABLE II

Differences in oviposition rate between female *Cryptus inornatus* reared from the two types of parasite larvae within their cocoons in overwintering field material:—
(a) Development merely slowed down by low temperatures.
(b) In true diapause.
The figures give the percentages of the total eggs produced by a number of similar females laid in each successive 10-day period ot their lives.

Age of female in days	Oviposition of females (a) from larvae not in true diapause		Oviposition of females (b) from larvae in true diapause	
	Actual number laid	Percentage of total	Actual number laid	Percentage of total
0-10	97	13.5	207	36.6
11-20	97	13.5	154	27.2
21-30	161	22.3	133	23.5
31-40	197	27.3	52	9.2
41-50	94	13.0	17	3.0
51-60	65	9.0	3	.5
61-70	10	1.4	-	-
Total	721	100.0	566	100.0

NEW SPECIES OF *EPHEMERELLA* FROM ILLINOIS
(Ephemeroptera)

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This paper presents descriptions of three new species of Ephemeroptera from Illinois, all belonging to the genus *Ephemerella*. These are forms segregated from material in the Illinois Natural History Survey collection; the types are deposited in that collection. Two of these species are closely related to the genotype, *E. excrucians* Walsh, and it was thought for some time that one or the other of them would prove to be that species. Study of the lectotype of *excrucians* showed, however, that both of these species are recognizably distinct from *excrucians*.

The third new species described here is known from the nymph only. All the specimens of this form were collected at least 20 years ago, and intensive more recent collecting in the same areas has failed to produce more specimens. The species may have actually disappeared by now from the Illinois fauna. It seems desirable to describe this form, in order to call attention to this distinctive nymph. More collecting and rearing in the states to the north of Illinois may quite possibly produce additional material of this species.

Ephemerella argo new species
Figs. 1, 5

Male.—Length of body 8 mm., of forewing 9 mm. General color light yellowish-tan, with brown markings. A member of the *invaria* group of species.

Head deep cream colored, with obscure darker markings on vertex between eyes and dorsad of anterior ocellus, fig. 1; bases of ocelli very dark gray, almost black; antennal flagellum five times as long as pedicel, scape and pedicel cream colored, flagellum brown; upper portion of compound eyes yellowish-tan, contiguous on meson. Thorax light yellowish-tan, vaguely tinted with brown on dorsal area of pronotum, at apex of mesoscutellum and on basal area of metanotum; all legs deep cream colored, apices of tibiae and second and third tarsal segments of foreleg slightly darkened; relative proportions of parts of foreleg: femur 17, tibia and first tarsal segment 26, second tarsal segment 11, third 9, fourth 7, fifth 4. Wings hyaline, with stigmatic area milky; anterior veins and anastomosed stigmatic crossveins of forewing slightly yellow. Ground color of abdomen light yellowish-tan, tergites shaded with brown: median dorsal line of all tergites unshaded, but on basal four abdominal tergites, brown

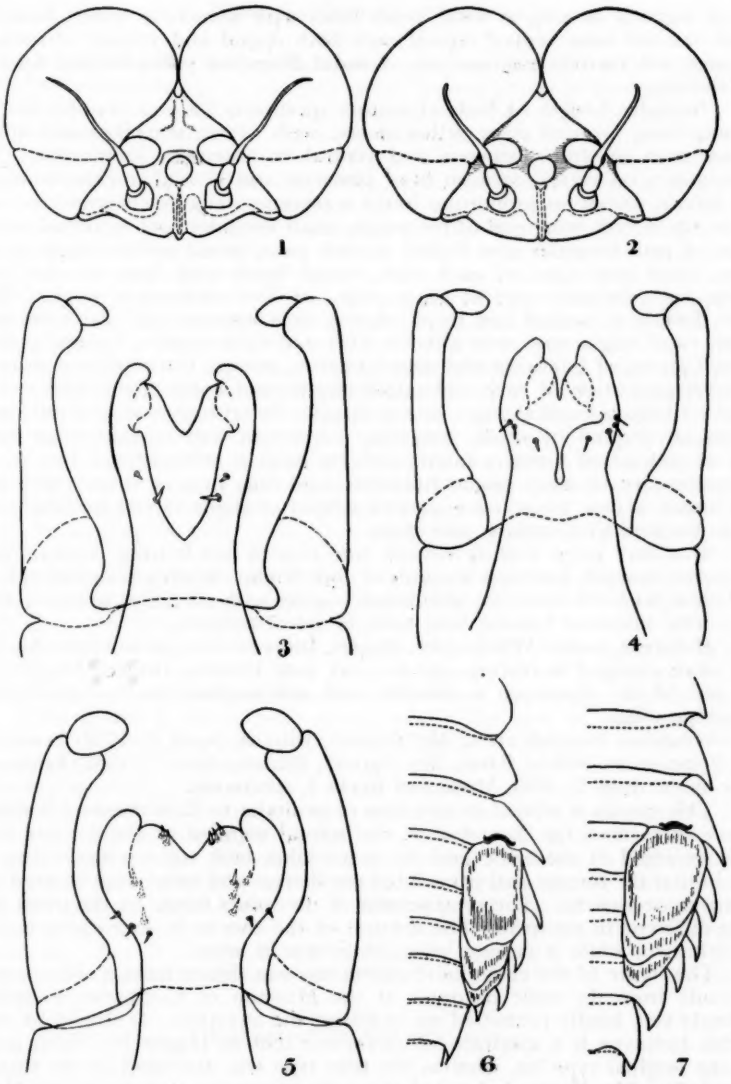

Fig. 1, Head, cephalic aspect, *Ephemerella Argo* ♂; 2, Head, cephalic aspect, *Ephemerella ora* ♂; 3, Genitalia, dorsal aspect, *Ephemerella excrucians* ♂; 4, Genitalia, dorsal aspect, *Ephemerella ora* ♂; 5, Genitalia, dorsal aspect, *Ephemerella argo* ♂; 6, Abdomen, right half, dorsal aspect, *Ephemerella simplex* N.; 7, Abdomen, right half, dorsal aspect, *Ephemerella lita* N.

shading covers entire balance of dorsal area, with a vague, darker brown spot at each antero-lateral angle of each tergite; on tergites five and six, brown shading reduced to relatively small areas near meson, but brown shaded area again enlarged to cover entire dorsal area on following tergites; sternites unmarked except for a vague, longitudinal brown line at lateral margin of each sternite. Genitalia, fig. 5., light yellowish-tan, forceps relatively short and stout; terminal

forceps segment as long as wide; penis lobes with numerous spines, basal ones dorsal, median ones ventral, apical ones both dorsal and ventral; distribution of spines not entirely symmetrical. Caudal filaments yellowish-tan, brown at articulations.

Nymph.—Length of body of mature specimens 7-9 mm.; caudal filaments 4-5 mm. long. Ground color yellowish-tan, with brown markings and areas as follows: area on frons between and ventral to antennae, longitudinal stripe between eyes on vertex, area on head posterior and ventral to compound eyes, wide lateral stripes on pronotum, broad transverse stripe on mesonotum, vague spot at tip of each wing pad of forewings, small irregular spot near base of each hindwing pad, irregular spot dorsad of each coxa, broad median band on each femur, band near apex of each tibia, broad band near base of each tarsus, median spot, between tips of wing pads, on first abdominal tergite, almost entire dorsum of second and third tergites, area between gill plates on fourth tergite, small vague spot near gills on fifth and sixth tergites, central portions, between plates, of following abdominal tergites, minute marginal spot near base of lateral projection of each abdominal tergite, and entire abdominal sternum except for narrow band at either lateral margin; dorsal brown areas of abdominal tergites interrupted by small, irregular, submedian and median spots; brown areas of abdominal sternites interrupted by median yellowish-tan spot at base of sternites five to nine; caudal filaments with one, two, or three vague transverse brown stripes; entire color pattern subject to slight variation: brown areas may be freckled with minute, pale spots.

Maxillary palpi well developed; fore femora not bearing teeth or spines on anterior margin, posterior margins of fore femora bearing scattered spicules; tarsal claws with 6-9 denticles; abdominal tergites without dorsal spines or tubercles; caudal filaments bearing long hairs in apical portion.

Holotype, male.—White river, Rogers, Indiana; nymph collected April 16, 1936, adult emerged in rearing cage in creek near Urbana, Illinois, May 7, 1936, Ross and Mohr. Specimen in alcohol, with subimaginal exuviae; genitalia on microscope slide.

Nymphs.—Wabash river, Mt. Carmel, Illinois, April 2, 1932, Frison and Ross, 2 specimens, White River, Mt. Carmel, Illinois, April 2, 1932, Frison and 4 specimens; April 4, 1940, Mohr and Burks 3, specimens.

This species is related in structure of genitalia to *E. excrucians* Walsh, as, in both *excrucians*, fig. 3, and *argo*, the second segment of the forceps is not greatly enlarged at the apex, and the penis lobes bear stout spines. The two differ in that the forceps and penis lobes are shorter and more stout in *argo* than they are in *excrucians*. The arrangement of the spines borne by the penis lobes is also different in the two. The dorsum of the thorax in *excrucians* is deep, reddish-brown, while it is light yellowish-brown in *argo*.

The figure of the genitalia of *excrucians* was drawn from a slide preparation made from the male lectotype at the Museum of Comparative Zoology. Mr. Banks very kindly permitted me to dissect the lectotype. It should be noted that this lectotype is a specimen of *excrucians* sent to Hagen by Walsh and is from the original type lot, whereas the true type was destroyed in the Chicago fire in 1871. Mr. Banks designated the male of *excrucians* now in the Hagen collection at the M. C. Z. as lectotype. The figure I give of the genitalia of this specimen differs slightly, but not significantly, from that published by McDunnough (1925, p. 169).

In this connection it may be noted that extensive collections made at Rock Island have failed to produce any specimens of *Ephemerella* that could be called *excrucians*. Since Walsh's time, the Mississippi and Rock Rivers have been so greatly altered by dredging and damming operations that the aquatic insect fauna has apparently changed almost completely. I have seen specimens of the true *excrucians* collected at lights near the Mountain Fork River, Hochatown, Okahoma.

Ephemerella ora new species

Figs. 2, 4

Male.—Length of body 7 mm., of wing 8 mm. General color yellow, with tan and brown markings. A member of the *invaria* group of species.

Head yellow, shaded with tan around bases of ocelli and between eyes, fig. 2; antennal flagellum four times as long as pedicel, scape and pedicel yellow, flagellum brown; upper portion of compound eyes in living insect pinkish-tan, contiguous on meson. Prothorax yellow, with tan shading on median dorsal area of pronotum; mesothorax mostly tan, but yellow at anterior tip of scutellum, on mesal area enclosed by inner parapsidal furrows, at wing bases along anterior wing processes, on praescutum and prealar bridge, on area around coxal cavities, along anterior margin of basisternum, and along median groove of furcisternum; metathorax yellow, tan dorsad of coxal cavities; all legs yellow, with apices of fore tibiae and apices of basal three foretarsal segments darkened; wing veins and membrane hyaline, with anterior two veins and stigmatic area very slightly yellowish. Abdominal segments with ground color yellow, basal and middle tergites with broad dorsal area heavily shaded with brown; apical tergites pinkish-tan (same shade as compound eyes in living insect); sternites yellow, with postero-lateral angles of eighth sternite pink; genitalia yellow, forceps, fig. 4, with second segment relatively slender, apex not enlarged, third segment as long as wide; penis lobes bearing a band of stout, dorsal spines in the basal position, no median nor apical spines present, lateral apical processes incurved, median, apical notch deep, narrow; caudal filaments light yellow, articulations black.

Female.—Length of body 7.5 mm., of wing 9 mm. Color pattern in general almost identical with that of male, but slightly lighter in shade. Caudal filaments white, with articulations black.

Holotype, male.—Mt. Carmel, Illinois, April 22, 1946, collected at light, Mohr and Burks. Specimen dry, on pin; genitalia on a microscope slide.

Allotype, female.—Same data as for Holotype. Specimen dry, on pin.

This species is related to *E. excrucians* on the basis of the second forceps segment of the male genitalia not being enlarged at the apex, by the presence of stout spines on the penis lobes, and by the dorsal dark brown shading of the abdominal tergites. The two differ in the number and distribution of the spines borne by the penis lobes, and in the shape of the penis lobes themselves; in *ora* the thorax is, also, tan and yellow, while it is deep, reddish-brown in *excrucians*. Were it not for the fact that the living male type of this species had pinkish-tan eyes, I would have placed it as a specimen of *excrucians* on the basis of macroscopic characters. Walsh, however, definitely stated that the eyes of his living specimens of *excrucians* were egg-yellow, while this species had them clearly pinkish-tan. Further study of this Mt. Carmel specimen showed, as well, the above noted genitalic and color differences between it and the lectotype of *excrucians*.

Ephemerella lita new species

Fig. 7

Nymph.—Length of body of mature specimen 8 mm., caudal filaments 5.5 mm. long. General color very light tan, with a few small, brown markings. A member of the *simplex* group of species.

Head and thorax light tan, without color markings; legs entirely unmarked except for a median brown band on each tarsus, claws brown at tips; dorsum of abdomen light tan, with a pair of submedian, brown spots at anterior margins of tergites 4-7, and on tergite 9; each gill socket at posterior margin of tergites 4-7 with dark brown border; tergites 6-8 with small, vaguely-defined brown lateral spot on area covered by mesal margins of gills; basal two-thirds of gills brown, gills very light tan at apex; abdominal sternites unmarked; caudal filaments with a single narrow, brown cross-band near base.

Head and body conspicuously hairy; head and thorax entirely without spines or tubercles, dorsal abdominal spines wanting; head semi-quadrate, with clypeo-genal margin beneath each antenna slightly incised, and occiput between eyes bearing a pair of tufts of long hair; maxillary palpi well developed. Pronotal shield semi-quadrate, with lateral margins almost parallel; thoracic legs with coxae not tuberculate; femora broad, somewhat flattened, margins bearing neither teeth nor spicules, apico-dorsal angle of each femur not produced as an acute spine; dorsal surface of each forefemur with a single, transverse row of long hairs located at the middle; all femora, tibiae, and tarsi with a conspicuous row of long hair at each lateral margin; tarsal claws without denticles. Postero-lateral angles of abdominal segments 2-9 produced, spine-like, fig. 7, a single pair of filamentous gills present on first abdominal segment; plate-like gills borne by segments 4-7, first pair of these semi-operculate; caudal filaments bearing spines at each articulation, these spines slightly longer in apical region of filaments than at base.

Holotype, female nymph.—Oakwood, Illinois, May 22, 1928, T. H. Frison. Specimen in alcohol.

Paratypes—Dixon, Illinois, Rock River, May 21-22, 1925, D. H. Thompson, 1 ♂, 4 ♀ nymphs. Rockford, Illinois, Rock River, June 2, 1927, D. H. Thompson, 1 ♀ nymph.

This species is similar to *simplex* McDunnough in that the head and body are conspicuously hairy, but lack spines and tubercles, in that the maxillary palpi are well developed, the tarsal claws lack denticles, and the plate-like gills are borne by abdominal segments 4-7, with the first pair semi-operculate. The two differ in that the clypeogenal margin of the head beneath the antennal sockets is incised in *lita*, while that margin is straight in *simplex;* the pronotal shield in *lita* is semi-quadrate, with the antero-lateral angles almost square and the two lateral margins almost parallel, while, in *simplex*, the antero-lateral angles of the pronotum are rounded, and the two lateral pronotal margins diverge slightly posteriorly; and the postero-lateral angles of the second and third abdominal segments are produced and spine-like in *lita*, while these angles are not produced in *simplex*, fig. 6. *E. lita* also differs from *hirsuta* Berner (1946, p. 70) in that *lita* completely lacks occipital, thoracic, and dorsal abdominal spines or tubercules.

LITERATURE CITED

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A NEW ANOBIID BEETLE FROM BRITISH COLUMBIA

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During the summer of 1946 specimens of anobiid beetles were received from G. Stace Smith of Creston, British Columbia, for identification. Mr. Smith believed that the specimens represented a new species and requested that the species be described.

This species resembles the European *Xestobium rufovillosum* DeGeer so closely that they can only be separated with great difficulty, but the habits of the two species are entirely different.

Xestobium abietis, new species

Elongate, robust, slightly expanded behind middle, piceous (antennae brownish yellow), subopaque, densely tessellate with short, yellowish-white hairs.

Head deeply sunk within the prothorax, slightly carinate around antennal bases; front convex; surface finely, densely, uniformly granulate-punctate, rather densely clothed with moderately long, recumbent, yellowish-white hairs. Antenna 11-segmented, slightly longer than head and prothorax united; first segment oval, robust; second narrower and about one and one-half times as long as first; third distinctly longer than fourth; fourth to eighth subequal in length; ninth and tenth subtriangular, subequal in length, twice as long as wide; eleventh segment elongate-oval, distinctly longer than tenth, widest at middle.

Pronotum as wide as elytra, one-third wider than long, moderately convex, narrowly flattened along lateral margins, not impressed along median line; lateral margins nearly parallel along middles; anterior margin with a broadly rounded median lobe, apical angles broadly rounded; base arcuately rounded at middle, sinuate at sides, the posterior angles broadly rounded; surface finely, densely, uniformly granulate-punctate, the granules scarcely separated.

Elytra twice as long as wide, slightly wider behind middle, the tips separately narrowly rounded; surface strongly convex, finely, densely, uniformly granulate-punctate.

Body beneath rather densely clothed with moderately long, recumbent, yellowish-white hairs; densely granulate-punctate; the granules coarser on prosternum, mesosternum and metasternum.

Length, 7.25-8 mm.; width, 3-3.5 mm.

Type locality.—Creston, British Columbia.

Type and paratype.—No. 58689, United States National Museum. *Paratypes* in the collection of G. Stace Smith.

Described from four specimens (one type) collected at the type locality, October 28 and November 11, 1945, by G. Stace Smith. These specimens were cut from pupal cells in a dry standing *Abies grandis*, miles from anywhere, in a dense forest at the base of a mountain.

This species is very closely allied to *Xestobium rufovillosum* DeGeer and is difficult to separate from that species. *Xestobium rufovillosum* differs from *Xestobium abietis* in being reddish brown, and not so uniformly or distinctly tessellated with yellowish-white pubescence on the elytra, and in having the pronotum and basal areas of the elytra coarsely granulate-punctate, with the granules distinctly separated. *Xestobium rufovillosum* is widely distributed throughout Europe and has been collected in the northeastern part of North America. It has been recorded in the literature as living only in dry hard woods, especially in timbers used in the construction of buildings. *Xestobium affine* LeConte is also allied to Xestobium *abietis* but it differs from *abietis* in being usually smaller and reddish brown, in having the elytra indistinctly tessellated with yellowish-white pubescence, and in not having the base of the pronotum distinctly sinuate on each side.

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